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THESIS

PRELIMINARY MEASUREMENTS AND CODE CALCULATIONS OF FLOW THROUGH A CASCADE OF DCA BLADING AT A SOLIDITY OF 1.67

by

William D. Molloy Jr.

June 1982

Thesis Advisor: Raymond P. Shreeve

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Preliminary Measurements and Code Calculations of Flow through a Cascade of DCA Blading at a Solidity of 1.67

by

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Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1974

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

An experimental program to obtain uniform inlet flow to the test blading in a large cascade facility designed to use inlet turning vanes, and to measure the conventional blade element performance, is described. Attempts to reduce non-uniformities (±1% in velocity) using screens were unsuccessful and so abandoned. Preliminary DCA blade element performance data were obtained without screens at one incidence angle before aero-mechanical problems with the inlet guide vane assembly curtailed testing. The blade surface pressure distribution at the one test condition compared very favorably with the distribution predicted using the NASA computer code QSONIC. Recommendations were made that would avoid the aero-mechanical problems encountered.

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LIST OF SYMBOLS

AVDR	Axial velocity-density ratio
Cp_1	Coefficient of pressure at the inlet
Cp_2	Coefficient of pressure at the outlet
Cp_{STATIC}	Coefficient of static pressure rise
C	Blade chord (inches)
D	Diffusion factor
i	Incidence angle (degrees)
P	Pressure (in. H_2O)
Q	Dynamic pressure (in. H_2O)
T	Temperature (^oR)
X	Non dimensional velocity
β	Air angle, measured in the cascade midspan plane with respect to the axial direction (degrees)
γ	Stagger angle
σ	Solidity (C/S)
$\bar{\omega}$	Loss coefficient

Subscripts

amb	Ambient
P	Pressure
PLENUM	Plenum (supply)
s	Static
wl	North wall, lower plane

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I. INTRODUCTION

The need for lightweight, fuel efficient gas turbines that are capable of developing large amounts of thrust or power has motivated a continuing drive to obtain more accurate predictions of the flow through turbomachinery. Cascade testing of blade rows has, in the past, been a logical and relatively inexpensive way to learn more about the phenomena involved in the flow through compressor and turbine stages. It is required more today in order to verify two dimensional and near-two dimensional analysis codes for flow through cascades. Such testing also provides two-dimensional blade element performance data which, in the absence of reliable analytical predictions, are required in the design of compressors and turbine stages. Reference 1 describes how cascade measurements are obtained using a cascade wind tunnel and then used in the design process.

Before subsonic cascade wind tunnel data can be accepted as being valid, the flow conditions must meet three requirements. These criteria are discussed in detail in Refs. 1, 2 and 3. First, any disturbance in the airflow should be caused by the test blades; that is, the inlet flow to the test section must be acceptably uniform.

Secondly, the measured flow characteristics should, ideally, be independent of spanwise position along the test

blades. The flow, ideally, should be two dimensional. Duval [Ref. 3] demonstrated that excellent flow conditions could be achieved in the Naval Postgraduate School Turbopropulsion Laboratory (NPS/TPL) Subsonic Cascade Wind Tunnel using test blades with an aspect ratio of approximately two. The absence of suction along the walls results however, in some degree of streamline contraction which is measured in terms of an Axial Velocity Density Ratio (AVDR).

The third requirement which must be satisfied is the periodicity of the inlet flow to the test section and of the outlet flow. Within one chord length of the leading edges of the test blades an upstream perturbation occurs as the streamlines adjust to negotiate the blade passages. Since the rectilinear cascade is simulating an infinite cascade of blades, the flow characteristics should be the same at corresponding axial and blade-to-blade positions within each blade passage. This same condition should be true at any measurement plane downstream of the test blading.

As described by Rose and Guttormsen [Ref. 4] several unique features were incorporated into the design of the NPS/TPL Cascade to ensure a two-dimensional and periodic flow at the test blading. Initial evaluations of the facility were conducted and reported in Refs. 3, 4, 5 and 6. Work by Moebius [Ref. 6] involved modifications to the tunnel plenum chamber which established satisfactory uniform

flow at the exit of the bellmouth contraction into the test section.

In order to maintain an aspect ratio close to 2.0 at a solidity of 1.67 Cina [Ref. 7], following the work of Duval [Ref. 3], used a cascade configuration of 20 blades with 3 inch spacing. Cina conducted a program of tests of DCA blading at five (5) different air incidence angles. With this cascade configuration, Cina found that the inlet flow to the test section was uniform in direction and of uniform static pressure, but with an imposed variation in velocity and stagnation pressure resulting from the wakes of inlet guide vanes. Although excellent periodicity was found over pairs of test blades, departure from strictly periodic conditions were detected from one blade passage to another. Cina explained this condition as being the result of the inlet guide vane wakes being separated at two inch intervals and entering a test section configured with a three inch blade spacing. Because of these flow conditions, Cina considered his results to be preliminary.

As a result of these findings the Cascade Wind Tunnel was modified so that inlet guide vanes were provided at one inch intervals. The object of the study reported herein was to obtain blade performance data on Cina's cascade with good periodic and uniform flow conditions. A necessary condition was to obtain agreement in the results for blade forces evaluated from surface pressures and from a momentum

balance. A second objective was to compare measured blade surface Mach numbers with the results of code calculations.

At the outset, it was first necessary to carry out an extensive testing program to verify the new inlet guide vane section and the effect the new spacing had on flow uniformity and periodicity. It was found that the uniformity of dynamic pressure was improved with the inlet guide vanes spaced at one inch intervals. Attempts were made to further improve the flow by the use of (various) wire screens placed downstream of the inlet guide vanes. These methods proved unsuccessful for the range of parameters tested and in fact aggravated the situation.

Cina's testing of the Double Circular Arc blading was repeated without screens and with the Cascade Wind Tunnel configured with the modified inlet guide vane arrangement. Limited measurements were obtained before aero-mechanical problems with the new IGV arrangement, at the higher tunnel speeds, were encountered.

The overall purpose of the testing program initiated by Cina was to obtain data with which to verify design optimization computer codes developed by NASA. Towards this goal a fast, reliable computer analysis code (QSONIC) for calculating the flow field about a cascade of arbitrary 2-D airfoils was obtained from NASA. The code was adapted and modified to run on the Naval Postgraduate School's IBM 370/3033 computer.

The program QSONIC was developed by NASA to overcome the Mach number limitations of the earlier program TSONIC [Ref. 8]. QSONIC is described in Ref. 9. Procedures for using the program QSONIC at the Naval Postgraduate School's computer facility are given in Appendix D. The procedures are documented for the case of the DCA blading in the NPS/TPL cascade wind tunnel. A program listing is included to document changes made to the code in order to adapt to the operating system of the NPS computer.

Preliminary results show that experimental measurements and code predictions are in very good agreement.

II. FACILITY DESCRIPTION AND MEASUREMENT APPROACH

A. SUBSONIC CASCADE WIND TUNNEL

The Naval Postgraduate School's Rectilinear Cascade Facility is shown in Fig. 1. A description of the facility as it was originally configured is given in Ref. 4. The test facility is an open cycle wind tunnel, designed for the purpose of testing cascades of axial-flow turbomachinery compressor or turbine blades. The unique design of the test section ensures that the airflow paths from the inlet guide vanes to all of the blades of the cascade test section are of equal length. This particular design was intended to eliminate the problems found in other cascade wind tunnels caused by having wall boundary layers of different thicknesses entering the cascade at different points.

As a result of the work reported in Ref. 1, two fine mesh screens were installed at the bellmouth entrance to improve flow stability. A follow-on study into the cascade performance was conducted by Bartocci and is reported in Ref. 5. As a result of Bartocci's findings, plenum turning vanes were installed to direct plenum inlet air towards the bellmouth entrance and to decrease the total pressure fluctuations present at the bellmouth entrance. Figure 2 shows the configuration of the plenum chamber as modified by Bartocci. Reference 6 describes work by Moebius that resulted

in further modification to the plenum chamber in which the original contraction was changed to two two-dimensional contractions in series. After this modification, acceptably small variations in velocity and flow angle were measured at the inlet guide vane station. Figure 3 shows the internal arrangement of the plenum chamber as modified by Moebius and as it was configured for the work presented here.

Using the plenum configuration shown in Fig. 3, Duval [Ref. 3] found that the wakes from the inlet guide vanes were not mixed out at the lower measuring plane of the test section but gave a well defined periodic variation in the impact pressure. The peak-to-peak variation was ±4% of dynamic pressure over two-inch periodic intervals. This condition was undesirable, but was tolerated while looking only to establish the values of parameters required to achieve two-dimensionality and periodicity. Since the inlet flow conditions were not uniform, mass averages were used to calculate properties at the inlet plane from probe measurements.

In order to achieve a solidity of 1.67 and aspect ratio of about 2, a blade spacing of 3 inches was required for the tests carried out by Cina [Ref. 7]. The tests showed unacceptable departures from blade-to-blade periodicity under conditions of high blade loading and the installation of additional guide vanes was recommended. The modification

to the inlet guide vane section of the tunnel resulting from Cina's findings is described in detail in Appendix A.

In the present work, several tests were completed with the tunnel further modified by the introduction of wire screens between the inlet guide vanes and the lower plane of the test section. Appendix B describes the screen material and the criteria used to select the particular screens used in this study.

B. INSTRUMENTATION

The instrumentation used in the present study is that which is described in detail in Ref. 7. Twenty static pressure taps were located on the north and south side walls. The taps on the south wall were connected to a water manometer board so that the uniformity of the static pressure distribution of the inlet and outlet could be monitored visually. Additionally, one upstream tap on each wall and one downstream tap on each wall (near the centerline) were also connected to the Scanivalve so that these static pressures were recorded.

Figure 4 shows the probe that was used for the upstream survey (at the lower plane). The probe was a United Sensor Corporation DA 125 probe, serial number A847-1, calibrated earlier at various Mach numbers and yaw angles in a calibration facility. The United Sensor Corporation DC-125-24-F-22-CD probe, serial number A981-2 (Fig. 5), which was used

at the upper plane was similarly calibrated. The characteristics of the probes were approximated analytically to facilitate automatic data reduction procedures. The calibration and application procedures were those given by Duval [Ref. 3]. Appendix B of Ref. 3 describes both the upstream and downstream probes in detail. The mounting and traversing mechanisms are described in Ref. 7.

C. REFERENCE MEASUREMENTS

Plenum chamber (supply) pressure and temperatures, and atmospheric pressure were recorded on each data scan. Plenum pressure was also displayed on a water manometer board. The total temperature in the test cascade was assumed to be the same as the plenum chamber temperature.

D. TEST BLADING

The double circular arc test blading modeled the midspan section of the stator of the compressor stage reported in Ref. 10. Coordinates describing the profile of the blading are listed in Table D-2. The leading edge and trailing edge are shown in detail in Fig. 6. A photograph of the centermost blade is shown in Fig. 7.

The three blades centrally located in the cascade were constructed with surface pressure taps along the midspan section as shown in Fig. 8. The centermost blade had 19 ports on each of the pressure and suction surfaces and one tap at the leading edge. The two blades adjacent to the

center blade had 3 surface pressure taps located on each of the pressure and suction surfaces. The surface pressure tap locations for the centermost blade are given in Fig. 9.

E. DATA ACQUISITION, REDUCTION AND ANALYSIS

Data were recorded, reduced, and plotted using the modified Hewlett Packard HP-3052A Data Acquisition System shown in Fig. 10. Reference 11 describes the system in detail. The system incorporated a HP-9845A desktop computer as a controller, with all components connected on the HP-98034A HP-IB Interface Bus. A NPS/TPL HG-78K Scanivalve Controller with two 48 port Scanivalves allowed the programmed acquisition of probe and blade surface pressure measurements.

The software used in the present study for acquisition, reduction and plotting of data were developed from software originally created by Duval and Cina. The programs are listed and described separately in Ref. 12.

The uncertainties in the measurements are listed in Table 1.

III. EXPERIMENTAL PROGRAM AND RESULTS

A. PROGRAM OF TESTS

The test program was in three phases. First, in order to verify the new inlet guide vane assembly, tests were conducted with no blading in the test section and with the upper and lower endwalls set parallel at 35° (design condition), 30° and 50° with respect to axial.

Secondly, tests were made of the effect of wire gauze screen materials in reducing non-uniformities in the flow entering the test section. Appendix B describes the type of screens used and how they were installed.

The last phase of the test program was a continuation of the work initiated by Cina. Table II lists the cascade configuration tested. One test was completed successfully before aero-mechanical problems were encountered and testing was halted until the causes were analyzed.

B. TEST PROCEDURES

1. Cascade Adjustments

In the first and second phases of testing, the same procedures were used to realign the cascade for each new configuration. The lower and upper end walls were set to the desired flow angle and the inlet guide vanes were set so that their trailing edges were approximately aligned with

the end walls. The flow was started, and the desired inlet dynamic pressure was set. All tests were run at an average dimensionless inlet velocity (X) of about .13, corresponding to an inlet flow dynamic pressure of 18 inches water. Before recording data, the water manometer board was checked to ensure that the distributions of wall static pressures at the inlet plane and outlet plane were acceptably uniform. If required, the inlet guide vanes were adjusted to obtain uniform static pressure to within ±0.5 inches of water.

In the third phase of testing, initially the procedures used by Cina [Ref. 7] were followed, namely: the lower end walls were set to the desired inlet air angle and the upper end walls were set approximately to the expected exit air angle. The inlet guide vanes were set very approximately and the cascade was turned on and set to an inlet dynamic pressure of 18 inches water. The upper end walls and the inlet guide vanes were adjusted in turn to obtain wall static pressure distributions upstream and downstream which were acceptably uniform. Using this procedure however it was found on occasion that the inlet air angle sensed by the probe at the lower plane at mid-span could be 2 or 3 degrees different from the setting of the end walls.

The following procedures was subsequently adopted. The lower end walls were set to the desired inlet air angle. The upper end walls were adjusted to be "wide open", to form a diverging passage in which, when the cascade was turned

on (to an inlet dynamic pressure of 18 inches water), the flow was completely separated. The inlet guide vanes were adjusted to obtain the required inlet air angle on the channel center line over the center 24 inches in the blade-to-blade direction. The upper end walls were then moved individually towards the vertical until the lower plane static pressure distribution was uniform and the upper plane static pressure distribution was acceptably uniform at a value close to atmospheric pressure. No readjustment of the inlet guide vanes was made.

2. Measurements

Probe surveys were carried out in the blade-to-blade direction at midspan at the upper and lower planes. In the first and second phases of testing, data were taken over approximately 24 inches of the test section at intervals of 0.25 inches. Also, in order to test the repeatability of measurements, repetitive samples were taken with the probe held fixed at midspan at the lower plane at the center, 10 inches to the right and 10 inches to the left of center.

During the third phase of testing, data were taken using the procedures established by Cina in Ref. 7.

C. VERIFICATION OF INLET GUIDE VANE (IGV) ASSEMBLY

The results of the first phase are presented (as shown in Table III) in Figs. 11 to 32. The results are arranged into groups. The first group (Figs. 11 to 14) are

measurements of tunnel conditions with the end walls set at 35 degrees. Plots of conditions at the lower plane are followed by plots of conditions at the upper plane.

Results for a wall angle of 30 degrees are given next (Fig. 15 to Fig. 18), followed by results for a wall angle of 50 degrees (Fig. 19 to Fig. 21). Data were taken over 24 inches at the lower plane, and also at the upper plane at 30°. At 50°, at the upper plane, only the center 12 inches were surveyed.

The degree of repeatability of conditions in the wind tunnel from test to test (with no change in wall setting) is demonstrated by the results plotted in Figs. 22, 23 and 24.

The last group of plots, Figs. 25 to 33, shows the degree of repeatability in the probe data from scan to scan. Data for these plots were obtained by holding the probe stationary at midspan in three specific blade-to-blade locations in turn and taking 50 repetitive scans of the channels normally recorded for survey profile data. The time interval for each scan was approximately 20 seconds.

D. TESTING WITH WIRE GAUZE SCREENS

The selection and installation of the wire gauze screens is described in Appendix B.

The measurements obtained with the various screen configurations are given (as shown in Table IV) in Figs. 34 to 45. The results are arranged in four groups.

The first group of plots (Fig. 34 to 40) give data obtained with the 16 mesh .0105 inch diameter wire screen installed. Over a blade-to-blade distance from -1.0 to 7.0 inches (Fig. 35) a peak-to-peak variation in velocity of about 1 percent was noted. This is slightly greater than the less than 1 percent (0.9 percent) variation noted over the same survey region without a screen installed (Fig. 12).

The results shown plotted in Figs. 41 and 42 were obtained with two screens installed. One screen (16 mesh, .0105 inch diameter) was installed as discussed in Appendix B, while the second screen (2 mesh, .0400 inch diameter) was attached across the duct at the leading edges of the inlet guide vanes.

The fourth group of plots (Figs. 43 to 46) show the results for two different single screens. Probe survey data for these screens was taken only at the lower plane. The results shown plotted in Figs. 43 and 44 are data obtained with a 4 mesh, .041 inch diameter wire screen installed. The variation in velocity in the blade-to-blade direction was as much as ±1.1 percent, peak-to-peak. The results shown in Figs. 45 and 46 are for a 5 mesh, .041 inch diameter wire screen. The variation in flow velocity was approximately ±1.5 percent, peak-to-peak.

E. PRELIMINARY TESTING OF DCA BLADES

The results contained in Tables V to IX and Figs. 47 to 60 are arranged in the following manner.

The results shown plotted in Figs. 47 to 60 are divided into two separate groups. The first group (Figs. 47 to 57) contain results which exhibit the quality of the wind tunnel flow conditions. The second group (Figs. 58 to 60) shows the blade forces (and surface pressures) from survey data. In the first group of figures, results are presented first to examine the inlet flow uniformity (Figs. 47 and 48); second, to examine the outlet flow periodicity (Figs. 49 to 53); and, finally, to examine outlet flow two dimensionality (Figs. 54 to 57).

All points are shown connected with straight lines.

IV. DISCUSSION OF EXPERIMENTAL RESULTS

A. EFFECT OF INLET GUIDE VANE (IGV) MODIFICATION

The probe survey data shown in Figs. 11 and 12 were taken at the lower plane, with the end walls set at 35 degrees. A turning angle of 35 degrees corresponded to the "design point" of the inlet guide vanes, when the airflow from the plenum chamber was at zero angle of incidence to the leading edge of the IGV's. These two figures show that the inlet plane total pressure at midspan in the blade-to-blade direction had a peak-to-peak periodic variation of about ±2 percent and therefore about a ±1 percent peak-to-peak variation in the velocity. Corresponding data from probe surveys at the upper plane (Figs. 13 and 14) show that periodic variations in total pressure were reduced to about 25% of the value at the lower plane by the mixing of the inlet guide vane wakes.

It can be seen in Figs. 15 to 21 that at "off-design" conditions for the IGV's (endwalls at 30° and 50°) there is a greater periodic variation in total pressure at the lower plane in the blade-to-blade direction than at the design point conditions. In Fig. 15 and Fig. 16, it can be seen that the periodic variations in total pressure are more pronounced with the flow from the plenum at a negative incidence angle to the IGV's (endwalls at 30°). Except for the first

8 data points in Fig. 15, there is a well defined period of about 1 inch of travel.

Figures 19 and 20 show the probe surveys conducted with endwalls at 50 degrees. At this off design condition the periodic variation in total pressure was considerably greater than the design point and the individual wakes from the inlet guide vanes were much less well defined.

The repeatability of the survey was examined at wall angles of both 50° and 30°. Figs. 22 to 24 show that the non-uniformities in the flow conditions were repeated to (generally) better than 0.5 percent of total pressure. The question was then, to what accuracy could the individual data points be repeated in successive samples. This was examined at several probe positions and the results given in Figs. 25 to 33 explain the departures in Figs. 22 to 24.

B. EFFECT OF WIRE GAUZE SCREENS

All testing with screens was conducted with the end walls and inlet guide vanes set to yield a flow angle of 35 degrees. The data obtained with screens installed were therefore compared with the data obtained without screens, shown in Figs. 11-14. The effect of the pressure drop across the screen on the pressure coefficient plotted in Figs. 34-35 should be noted. With the first screen installed the drop in total pressure from plenum to the probe in the lower plane was about 10 inches of water (plenum pressure minus total

pressure measured by the probe at the lower plane). Without the screen (at design conditions), the pressure drop from the plenum to the probe at the lower plane was approximately 2.0 inches of water. Since Q_{ref} was defined as the difference between plenum pressure and lower wall static pressure, the value of Q_{ref} with the first screen installed was about 28 inches water and without the screen installed, about 20 inches water. In comparing the peak-to-peak variation in P1 seen in Fig. 11 with that obtained with the first screen installed in Fig. 34, the difference in the values of Q_{ref} must be considered. Examinations showed that the peak-to-peak variation in velocity remained at approximately 1% when the screen was installed.

Figures 38 to 40 are plots of data obtained during a spanwise traverse of the probe at the lower plane. These figures show that the pressure drop through the screen and turning vanes was nearly uniform over approximately 8.0 inches of the 10.0 inch span of the tunnel.

In an attempt to generate upstream disturbances that might trigger early boundary layer transition on the IGV's and increase the rate of mixing of the wakes, a second screen was attached to the leading edge of the IGV's. The results in Figs. 41 and 42 showed that this was not the case and in fact the second screen increased the magnitude of the nonuniformities at the lower survey plane. Measurements made with a single 4 mesh (Figs. 43 and 44) and a single 5 mesh

screen (Figs. 45 and 46) of similar blockage showed that neither screen influenced the flow in a particularly favorable manner. The 4 mesh screen caused the peak-to-peak variation in velocity to be about ±1.1 percent, while the 5 mesh screen caused the variation to be about ±1.5 percent. This compared unfavorably with the variation obtained without any screen installed which was less than ±1 percent.

It was therefore decided to proceed with measurements of the test cascade without using screens.

C. PRELIMINARY TESTING OF DCA BLADES

1. Inlet Uniformity

The probe survey at the lower plane in Fig. 48 shows that the inlet plane total pressure at midspan varied in the blade to blade direction less than 0.5 inches of water, with no well-defined spatial period. This was an improvement in the inlet conditions found by Cina [Ref. 7: Fig. 16]. That the spatial period was not well defined agreed with the findings presented earlier in this report. The wall static pressure distribution (Fig. 47) showed small variations (less than 0.5 ins. water peak-to-peak at the lower plane, .4 ins. water peak-to-peak at the upper plane).

2. Two-Dimensionality

The data in Figs. 54 to 57 show that, at the downstream plane, an area of (spanwise) nearly uniform conditions

existed near the centerline of the cascade. Reference 2 points out that at higher loadings it is difficult to establish a substantial spanwise area of uniform flow in the region near the suction side of the blade. This difficulty is evident in the data shown in Figs. 54 and 55 which show that only about 20% of the spanwise distance is acceptably uniform. It is noted that Cina also found reduced areas of uniform flow at this incidence angle; however, 30-40% of the spanwise distance was found to be acceptably uniform in his case. The difference could be the result of the reduced spacing of the IGV's and its effect on the side wall boundary layers.

Figure 58 shows results for inlet and outlet flow angles and blade force vectors derived in two ways as shown in Appendix B of Ref. 7. These two methods are first the applications of momentum conservation to probe survey data and second, the integration of surface pressures measured over the blade area. Reference 2 points out that for truly two dimensional flow the blade forces derived from the two methods should be the same. As shown in Fig. 58 the magnitudes and the directions of the two vectors representing the blade forces are in reasonable agreement. It is noted however that at this particular incidence angle Cina [Ref. 7] measured blade forces that were in total agreement in direction but disagreed slightly in magnitude. The values of the

force magnitudes were about 1.5% lower than those measured by Cina.

3. Periodicity

As can be seen in Figs. 50 and 51 the total pressure and velocity qualitatively repeated fairly well over three central blade passages. Acceptably small quantitative differences are noted. There was also a small but measurable difference in the surface pressures on adjacent blades, as is evidenced in Fig. 49.

4. Blade Performance

Figures 59 and 60 are plots of the pressure and velocity distributions respectively over the centermost blade. These results compare favorably to those obtained by Cina for an incidence angle of 5.3°.

Table IX contains the blade performance parameters deduced from the probe survey data listed together with the data obtained for corresponding test parameters in Ref. 7. While differences in two sets of data are evident, the differences are not large. It is noted that the value of the loss coefficient was only 10% lower than was measured by Cina, but the AVDR was less than 2% different from unity rather than the 6.5% measured by Cina. Further measurements need to be made, particularly in the light of the following discussion, before stronger conclusions can be drawn.

5. Aero-Mechanical Problems Encountered

Fifteen cascade tests were made while evaluating the new inlet guide vane assembly and testing the wire screens. All runs were made without test blades installed, with a plenum total pressure of about 20 inches of water and with the upper and lower end walls parallel. No difficulties were encountered in establishing the desired flow conditions or in using the inlet guide vanes to arrive at a satisfactory distribution of wall static pressures.

The first time the Cascade Wind Tunnel was set up with test blades installed to take data at an air inlet angle of 39.2°, the tunnel operated normally and the test was completed. (The data from this test were subsequently found to be highly suspect and are not reported here.) During the next test, with an inlet air angle of 42.4, the start-up appeared normal and previously established procedures were used to arrive at a satisfactorily uniform wall static pressure distribution. Tunnel operation appeared to be normal while taking data, but on shutdown a very noticeable high frequency vibration was encountered. Examination of the inlet guide vanes revealed that about 40% of the 60 blades were damaged. Damage included chips missing from the trailing edges, blades bent, cracks at the weld where the blade is joined to its support and indications that the suction side near the leading edge of one blade had been vibrating

against the pressure side near the leading edge of an adjacent blade.

After the inlet guide vanes had been repaired and reinstalled extreme care was used at the beginning of the next test to adjust the inlet guide vanes, with two individuals monitoring the movement of the adjustment mechanism. (IGV adjustment mechanism is described in detail in Appendix A.) A lack of stiffness in the mechanism was suspected as having been a contributing factor to the failure.

One successful test was completed at an inlet flow angle of 42.4° and these data were discussed above.

With the next cascade configuration set, at an air inlet angle of 45.9°, when the IGV's were adjusted after starting up, high frequency vibrations were again experienced. The wind tunnel was shut down and no further testing was attempted at plenum total pressures as high as 20 inches of water gauge.

The difficulty encountered with the IGV's is not fully understood, however the lack of stiffness present in the actuation of the two separate rows of vanes is suspected of having allowed the problem to occur. Certainly, the possibility of an aerodynamic flutter condition being present (due to the misadjustment perhaps) can not be ignored. It was noticed after the initial failure that the lead screw which adjusts the IGV's could be turned but the blades mounted from only one side would be caused to rotate. This

could lead to the trailing edge of one blade contacting the trailing edge of an adjacent blade and effectively closing the blade passages.

Also, the holes in which the cylindrical shanks of the IGV's were held were found not to be uniformly machined. As much as 0.1 inches of movement at the tip of some vanes was possible while others could barely move. (The most seriously damaged blades were found in or adjacent to the larger holes.)

The tendency for the mechanism to "hang-up" on one side would be greater as the vanes became more highly loaded. It is noted that the IGV problem was encountered first when going to increased incidence angles with the compressor test cascade installed. In setting a constant plenum total pressure of 20 inches of water gauge, the static pressure increase across the test blades to a constant atmospheric pressure at the downstream side implies that a progressively increasing dynamic pressure was being generated out of the turning vanes. This can be seen in Table IX, where Q_1 for the test at $\beta_1 = 42.4$ was 25 inches of water.

V. COMPUTATIONAL PROGRAM

A. DESCRIPTION OF QSONIC

The computational code, QSONIC, was developed by the staff at the NASA Lewis Research Center.[1] This code is able to calculate the blade-to-blade flow conditions in turbomachinery blade rows assuming inviscid flow but including streamtube convergence and radius change in the throughflow direction. QSONIC is flexible enough to allow the input of the appropriate boundary conditions to calculate the flow through the test blading in the Subsonic Cascade Wind Tunnel. The program uses a fully conservative solution of the full potential equation combined with the finite volume method on a body-fitted mesh. QSONIC uses an artificial density imposed in the transonic region, if such a region exists, to ensure stability and the capture of shock waves.

The analysis used by QSONIC is a combination of transonic analysis methods to calculate the flow conditions in the vicinity of a cascade of airfoils. A conservative form of the full potential equation is discretized at every point of a body fitted periodic mesh and a mass balance is calculated through the finite volume surrounding the point. The volume

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[1] The help and advice received from Charles Farrell at NASA Lewis R.C. in the process of adapting QSONIC to the NPS computer is gratefully acknowledged.

is corrected three dimensionally for any change in streamtube thickness along a streamtube, if a quasi-3D solution is desired. Either elliptic or hyperbolic non-linear partial differential equations are used, depending on the local Mach number.

The analysis used in developing QSONIC made the following assumptions:

1) The airflow is inviscid and adiabatic.
2) The airflow relative to the test blades is steady.
3) Air is a perfect gas with constant specific heat.
4) The airflow is isentropic and any discontinuities such as shocks are so weak that they may be approximated as isentropic jumps.
5) There is no velocity component normal to the streamsurface.
6) The airflow relative to a fixed reference frame (i.e. absolute velocity) is completely irrotational.

Assumption 4 requires that the peak local relative Mach number on a blade surface be 1.4 or less. The Mach numbers measured in test blades in the Subsonic Cascade Wind Tunnel would be well within this limit. However, this limitation would probably preclude the use of QSONIC for analysis of the flow field in the NPS transonic cascade wind tunnel.

There are some combinations of blading geometry and flow conditions which cause unsatisfactory results to be generated. For example, because of assumptions 1 and 6, sharp leading edges at high incidence angles (more that a few degrees) cause large velocity peaks in the blade surface as

the flow tries to turn from the stagnation point to the suction surface.

Reference 9 gives a detailed description of QSONIC and the solution method used including the governing equations. Appendix D describes the operating procedures to use QSONIC on the Naval Postgraduate School's IBM 370/3033 computer. Appendix D also describes the input and output required as applicable to the Subsonic Cascade Wind Tunnel.

B. APPLICATION TO THE TEST CASCADE

Appendix D describes in detail the generation of the input required for QSONIC when applied to test blading in the Subsonic Cascade Wind Tunnel facility. In the present work one comparison of code calculations and measured data was made before testing was stopped. The comparison was for an inlet flow angle (β_1) of 42.4°.

Tables D.1 and D.3 show the input data generated. Table D.6 shows the flow solution output by QSONIC. The flow calculated on the blade surface, using a 15 by 97 mesh, was examined. Figure 61 is a plot of the calculated Mach number along the blade surface using two dimensional inputs. Figure 62 is a plot of computed Mach number incorporating quasi-three dimensional effects. The method of incorporating quasi-three dimensional effects is explained in Appendix D.

C. COMPARISON OF CODE CALCULATIONS AND MEASURED DATA

Table VII lists the data measured in the cascade wind tunnel. C_{p1}, C_{p2} and X_{vel} are defined in Appendix C. The surface Mach number distribution measured on the center blade is shown plotted in Fig. 63.

For comparison, the computed two dimensional, computed quasi-three dimensional, and the Mach number measured in the cascade wind tunnel are plotted together in Fig. 64.

Excellent agreement between all three cases is seen. As would be expected, the greatest difference between measured and calculated data is near the leading edge in the suction side and at the trailing edge of the blade.

VI. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the first part of the present study, to evaluate the effects of the altered inlet guide vane spacing on flow uniformity and periodicity, the following conclusions were drawn:

1. With the inlet guide vanes operating at design, the peak-to-peak variation in velocity was about ±1%, and there was a well defined spatial period of about 1 inch.
2. Operating the cascade wind tunnel in a configuration that requires the inlet guide vanes to be set to other than zero incidence resulted in peak-to-peak variations in velocity greater than ±1% and a spatial period that was less well defined.

The second part of the study, to evaluate the use of wire gauze screens to further reduce the non-uniformities in the flow field, led to the following conclusions:

1. A 16 mesh screen with a blockage factor of .69 had a slightly aggravating effect in the variation in velocity. The peak-to-peak variation in velocity with the screen installed was slightly greater than with no screen installed. This occurred at the expense of a pressure drop of about 10" of water across the screen.
2. The use of screens with similar blockage but with larger mesh and larger diameter wires resulted in larger peak-to-peak variations in the velocity at the lower plane.

The overall objective of the present study was to measure the performance of the DCA test blading. Because of aero-mechanical problems encountered with the inlet turning vanes the performance of the blades was obtained at one

incidence angle only. The following was concluded from the limited test program:

1. As a result of the reduced inlet guide vane spacing the variations in velocity and total pressure at the inlet plane were much less than those reported by Cina.
2. Good periodicity was found from one blade passage to another.
3. An acceptable region of spanwise uniformity (20-40% of blade span) was found at the downstream plane at the one test condition reported. However, this was less than was previously reported for the same incidence angle.
4. The blade forces derived from the integration of surface pressure measurements and probe survey data were in close agreement in both magnitude and direction.
5. The Mach number measured by surface pressure taps over the surface of the blade and Mach number calculated using the program QSONIC were in excellent agreement qualitatively and reasonable agreement quantitatively.
6. The specific reasons for the aero-mechanical problems experienced with the inlet turning vanes have not been identified completely.

Based on these conclusions and other observations, the following recommendations are made:

1. Use of the present inlet guide vane assembly and adjustment mechanism for testing at inlet dynamic pressures higher than about 15 inches of water is unsafe. There are three possible solutions to this problem.
    a) Operate only within the dynamic pressure range of 10-15 inches of water.
    b) Modify the new inlet guide vane assembly so that the vanes are supported at both ends on their axes of rotation. [Supporting the IGV's from both ends would prevent flapping vibrations of the (presently) cantilevered vanes. Such vibrations, when the vanes are supported alternately from opposite ends and the gaps are small compared to the chord, might lead to a potentially destructive flutter mode at particular flow velocities.]

    c) Replace the entire inlet turning vane section with one of entirely new design.

2. The procedure should be adopted immediately of adjusting the vanes and walls of the cascade at lower values of the dynamic pressure before increasing the blower speed to the desired operating condition.

3. More time needs to be spent to examine the flow field produced between the guide vanes and the test blades, and to establish the effects of the movement of the tail boards. The uniqueness of the flow field when the wall static pressure uniformity is used as a criterion of good inlet flow, needs to be examined by conducting repetitive tests at nominally similar test parameters. Only when the adjustment of the flow in the facility and the quality of the flow itself is fully understood should the measured blade performance data be accepted as final.

4. The upper electrical yaw adjustment mechanism should be replaced with a manual system to greatly decrease the time required to achieve probe pressure (angle) balancing.

5. Develop the computer code necessary to take advantage of the plotting data created by QSONIC.

6. Modify the data acquisition and reduction software for the HP 9845 so that real time plots of blade performance parameters can be displayed.

TABLE I. MEASUREMENT UNCERTAINTY

Item	Description	Method	Uncertainty
x	Blade-to-Blade dimension x = 0 in. West end x = 60 in. East end	Position Potentiometer	±.01 in.
z	Spanwise dimension z = 0 in. North wall z = 10 in. South wall	Position Potentiometer on probe mount	±.01 in.
β_1	Inlet flow yaw angle	Angle Potentiometer on probe mount (hand adjustment)	±.2 deg.
β_2	Outlet flow yaw angle	Angle Potentiometer on probe mount (motor driven adjustment)	±.5 deg.
P_{plen}	Plenum total pressure	Static tap in plenum chamber $V \simeq 0$	±.01 in. H_2O gauge
P_s	Static pressure at the test plane	Calibrated pneumatic probe	±.1 in. H_2O gauge
$P_{w\ell}$	Static pressure at x = 0 in., y = -16.25 in., z = 0 in.	Static tap on North wall	±.01 in. H_2O gauge
P_{ATM}	Atmospheric pressure	Absolute Strain Gauge Transducer	±.3 in. H_2O
P	Pressure	Scanivalve Transducer	±.01 in. H_2O gauge

TABLE II. CASCADE CONFIGURATION FOR DCA BLADE TESTS

Constant Parameters

Number of Blades	20
Spacing (Pitch)	3 inches
Chord	5.01 inches
Solidity	1.67
Thickness	7.0 percent of chord
Camber Angle	45.72 degrees
Stagger Angle	14.72 degrees

Variable Parameters

β_1	42.4 degrees
i	5.3 degrees

TABLE III. SUMMARY OF MEASUREMENTS WITHOUT SCREENS

β_1	Survey Plane	Survey Direction	Fig. Nos.	Purpose
35	Lower	B-B (24 inches)	11 & 12	Flow Field Determination
	Upper	B-B (24 inches)	13 & 14	
30	Lower	B-B (24 inches)	15 & 16	
	Upper	B-B (24 inches)	17 & 18	
50	Lower	B-B (24 inches)	19 & 20	
	Upper	B-B (12 inches)	21	
50	Lower	B-B (24 inches)	22 & 23	Survey Repeatability
30	Lower	B-B (24 inches)	24	
30	Lower	Fixed Probe (10" L. of ℄)	25-27	Point Repeatability
		(on ℄)	28-30	
		(10" R. of ℄)	31-33	

TABLE IV. SUMMARY OF MEASUREMENTS WITH SCREENS
($\beta_1 = 35^{\circ}$)

	Screen	Survey Plane	Survey Direction	Fig. Nos.
1.	16 mesh .0105 wire	Lower	B-B	34 & 35
		Upper	B-B	36 & 37
		Upper	Spanwise	38-40
2.	16 mesh .0105 wire + 2 mesh ahead of IGV's	Lower	B-B	41 & 42
3.	4 mesh .041 wire	Lower	B-B	43 & 44
4.	5 mesh .041 wire	Lower	B-B	45 & 46

TABLE V. PROBE DATA, UPPER PLANE AT MIDSPAN (i = 5.3°)

DATA FROM FILE UBRED2:T14
BLADE TO BLADE TRAVERSE MIDSPAN

UPPER PLANE

Point	Loc(in)	Beta	Q/Q1bar	Ps/Q1bar	Pt/Q1bar	X/Xbar
1	-7.31	-1.59	.5686	.2614	.0920	.6475
2	-6.84	-.84	.5532	.2669	.1041	.6381
3	-6.37	-.83	.4276	.2561	.2396	.5630
4	-5.87	-2.56	.5096	.2707	.1380	.6149
5	-5.67	-2.56	.5622	.2638	.0995	.6428
6	-5.48	-2.56	.5780	.2534	.0902	.6530
7	-5.23	-1.79	.5739	.2573	.0916	.6503
8	-5.04	-1.79	.5747	.2626	.0927	.6483
9	-4.80	-1.78	.5697	.2578	.0952	.6480
10	-4.60	-1.78	.5705	.2588	.0901	.6495
11	-4.41	-1.78	.5687	.2575	.0955	.6478
12	-4.16	-1.36	.5650	.2591	.0994	.6451
13	-3.96	-1.35	.5629	.2606	.0987	.6443
14	-3.78	-1.36	.5462	.2682	.1123	.6333
15	-3.58	-1.36	.4863	.2684	.1739	.5978
16	-3.39	-1.35	.4349	.2611	.2269	.5677
17	-3.19	-1.88	.4239	.2571	.2456	.5597
18	-3.00	-3.16	.4886	.2738	.1668	.5989
19	-2.80	-2.41	.5467	.2744	.1108	.6318
20	-2.60	-2.19	.5717	.2636	.0962	.6461
21	-2.40	-1.92	.5751	.2608	.0951	.6482
22	-2.20	-1.92	.5773	.2597	.0926	.6498
23	-2.01	-1.92	.5814	.2599	.0926	.6507
24	-1.81	-1.92	.5810	.2612	.0951	.6493
25	-1.61	-1.48	.5765	.2606	.0901	.6502
26	-1.42	-1.47	.5755	.2644	.0912	.6483
27	-1.22	-1.48	.5748	.2626	.0947	.6476
28	-1.02	-1.46	.5679	.2661	.1004	.6430
29	-.83	-1.47	.5378	.2726	.1217	.6267
30	-.64	-1.46	.4704	.2693	.1954	.5862
31	-.44	-1.47	.4140	.2553	.2698	.5497
32	-.25	-1.47	.4295	.2658	.2442	.5594
33	-.05	-3.00	.5011	.2740	.1616	.6040
34	.15	-2.32	.5562	.2718	.1040	.6371
35	.36	-1.74	.5776	.2672	.0879	.6488
36	.55	-1.71	.5795	.2636	.0865	.6509
37	.75	-1.83	.5880	.2591	.0872	.6541
38	.95	-1.83	.5915	.2613	.0833	.6554
39	1.15	-1.83	.5902	.2591	.0844	.6555
40	1.35	-1.83	.5903	.2587	.0833	.6561
41	1.85	-1.83	.5810	.2601	.0922	.6506
42	2.35	-1.83	.4490	.2598	.2202	.5749
43	2.85	-1.84	.4421	.2670	.2278	.5681
44	3.34	-2.01	.5722	.2600	.0990	.6465
45	3.85	-2.01	.5763	.2597	.0972	.6481

TABLE VI. PROBE DATA, LOWER PLANE AT MIDSPAN (i = 5.3°)

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DATA FROM FILE LBRED2:T14
BLADE TO BLADE TRAVERSE MIDSPAN



LOWER PLANE

Point  Loc(in)     Beta    Q/Q1bar     Ps/Q1bar     Pt/Q1bar     X/Xbar
**************************************************************************
  1     -4.00     -42.43    .9533      -.1372        .0932       .8457
  2     -3.50     -42.42    .9603      -.1444        .0967       .8474
  3     -3.00     -42.42    .9567      -.1427        .0996       .8454
  4     -2.50     -42.44    .9614      -.1519        .1031       .8480
  5     -2.00     -42.43    .9741      -.1469        .0871       .8524
  6     -1.50     -42.43    .9767      -.1493        .0875       .8532
  7     -1.00     -42.43    .9722      -.1481        .0889       .8522
  8      -.50     -42.43    .9743      -.1564        .0921       .8546
  9      0.00     -42.43    .9799      -.1567        .0935       .8540
 10       .50     -42.42    .9849      -.1592        .0854       .8585
 11      1.00     -42.43    .9814      -.1604        .0850       .8593
 12      1.50     -42.43    .9871      -.1628        .0779       .8635
 13      2.00     -42.43    .9787      -.1615        .0890       .8582
 14      2.50     -42.43    .9742      -.1632        .0971       .8556
 15      3.00     -42.41    .9731      -.1650        .1059       .8526
 16      3.50     -42.42    .9807      -.1663        .0924       .8589
 17      4.00     -42.44    .9736      -.1651        .0968       .8567
```

TABLE VII. CENTER BLADE DATE (i = 5.3°)

X/C	Y/C	Cp1	Cp2	Mach	Nvel
PRESSURE SIDE CENTER BLADE					
.0007	.0054	.6655	.4573	.1785	.0796
.0160	.0019	.6417	.4140	.1849	.0824
.0319	.0066	.5240	.1999	.2136	.0951
.0479	.0112	.5287	.2083	.2126	.0946
.0858	.0215	.4871	.1327	.2219	.0988
.1218	.0303	.4818	.1230	.2231	.0993
.1956	.0452	.4700	.1017	.2257	.1004
.2695	.0576	.4757	.1120	.2244	.0999
.3433	.0663	.4764	.1133	.2243	.0998
.4192	.0716	.4892	.1366	.2215	.0986
.4930	.0736	.4871	.1327	.2219	.0988
.5669	.0727	.4771	.1146	.2241	.0997
.6407	.0678	.4956	.1482	.2201	.0979
.7146	.0601	.4889	.1359	.2216	.0986
.7884	.0487	.4949	.1469	.2202	.0980
.8283	.0411	.4672	.0965	.2263	.1007
.8683	.0327	.4537	.0719	.2292	.1020
.9082	.0230	.4245	.0189	.2354	.1047
.9481	.0123	.3815	-.0594	.2443	.1086
.9880	.0006	.2778	-.2482	.2646	.1175
SUCTION SIDE CENTER BLADE					
.0160	.0227	-1.3641	-3.2355	.4973	.2171
.0319	.0310	-.7756	-2.1647	.4249	.1867
.0479	.0389	-.4980	-1.6597	.3878	.1709
.0858	.0563	-.3541	-1.3979	.3675	.1622
.1218	.0710	-.3431	-1.3778	.3659	.1615
.1956	.0970	-.2923	-1.2853	.3585	.1583
.2695	.1170	-.2500	-1.2084	.3522	.1556
.3433	.1309	-.2038	-1.1243	.3453	.1526
.4192	.1399	-.1540	-1.0338	.3377	.1493
.4930	.1432	-.0854	-.9090	.3270	.1447
.5669	.1412	-.0584	-.8599	.3227	.1428
.6407	.1339	.0102	-.7351	.3116	.1380
.7146	.1209	.0631	-.6387	.3028	.1342
.7884	.1021	.1456	-.4887	.2886	.1280
.8283	.0895	.1911	-.4059	.2805	.1245
.8683	.0755	.2326	-.3303	.2730	.1212
.9082	.0593	.2636	-.2740	.2673	.1187
.9481	.0407	.2842	-.2365	.2634	.1170
.9880	.0206	.2948	-.2171	.2613	.1161

TABLE VIII. ADJACENT BLADES DATA (i = 5.3°)

X/C	Y/C	Cp1	Cp2	Mach	Avel
PRESSURE SIDE LEFT BLADE					
.1218	.0303	.4014	-.0231	.2402	.1068
.4192	.0716	.4619	.0868	.2275	.1012
.8283	.0411	.4491	.0635	.2302	.1024
SUCTION SIDE LEFT BLADE					
.1218	.0710	-.3438	-1.3791	.3660	.1615
.4192	.1400	-.1505	-1.0273	.3371	.1491
.8283	.0895	.1975	-.3943	.2794	.1240
PRESSURE SIDE RIGHT BLADE					
.1218	.0303	.4640	.0907	.2270	.1010
.4192	.0716	.4658	.0939	.2266	.1008
.8283	.0411	.4597	.0829	.2279	.1014
SUCTION SIDE RIGHT BLADE					
.1218	.0710	-.3285	-1.3513	.3638	.1606
.4192	.1400	-.1519	-1.0299	.3374	.1492
.8283	.0895	.1911	-.4059	.2805	.1245

TABLE IX. BLADE PERFORMANCE DATA

	Present Results	From Ref. 7
β_1	42.42	42.42
i	5.3	5.3
β_2	1.85	0.4
δ	10.44	9.0
D	0.455	0.46
$\bar{\omega}$	0.037	0.041
$\frac{\omega \cos^3 \beta_2}{2 \sigma \cos^2 \beta_1}$	0.020	0.023
$\frac{\omega \cos \beta_2}{2\sigma} (\times 10^2)$	1.09	1.242
AVDR	1.015	1.065
$C_{P_{STATIC}}$	0.413	0.351
C_{xM}	-1.385	-1.380
C_{yM}	-0.669	-0.566
C_{xB}	-1.330	-1.476
C_{yB}	-0.572	-0.645
$\bar{Q}_1$ (in. H_2O)	25	22
$\bar{X}$	.14	.12

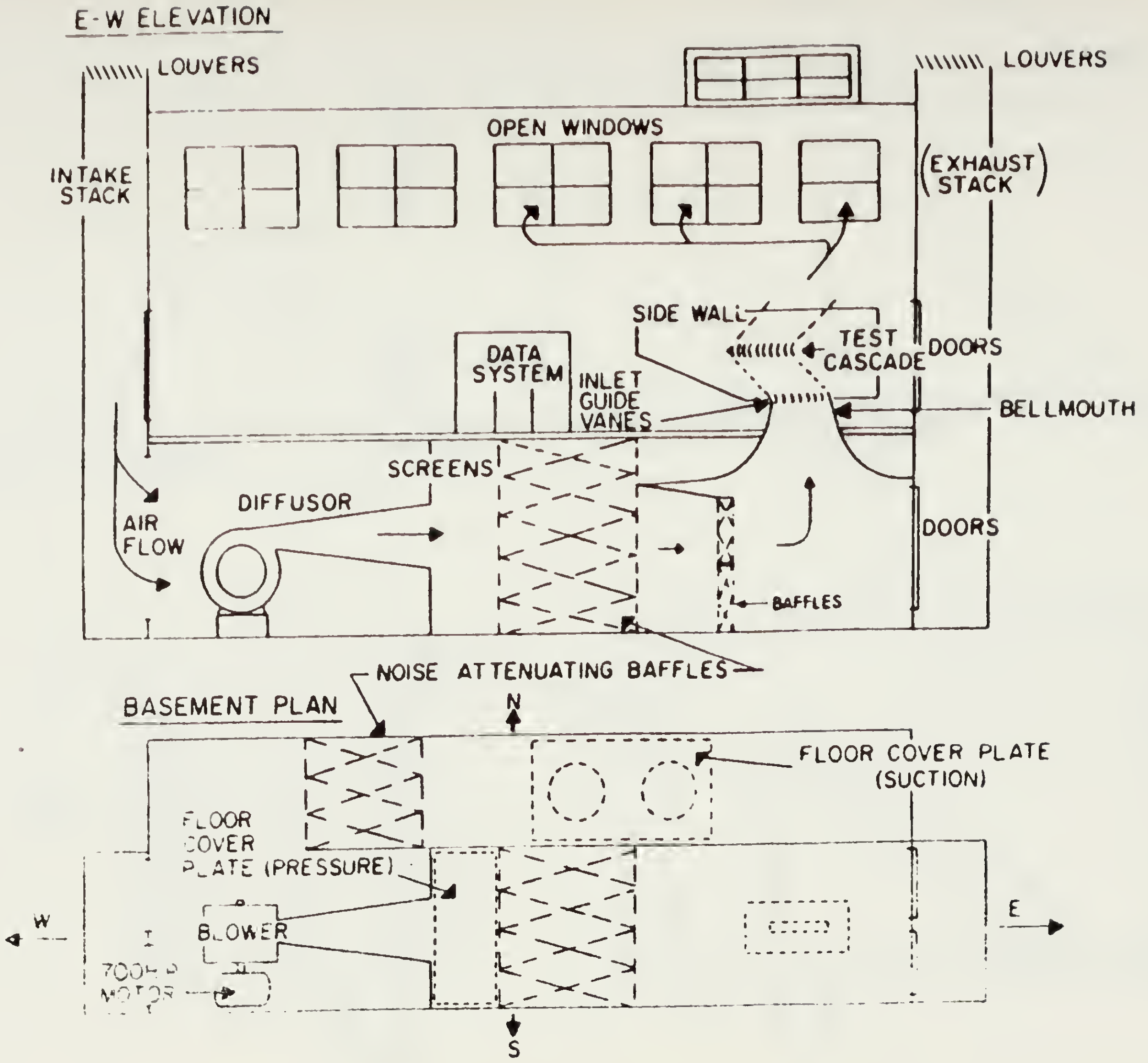


Fig. 1. Subsonic Cascade Facility

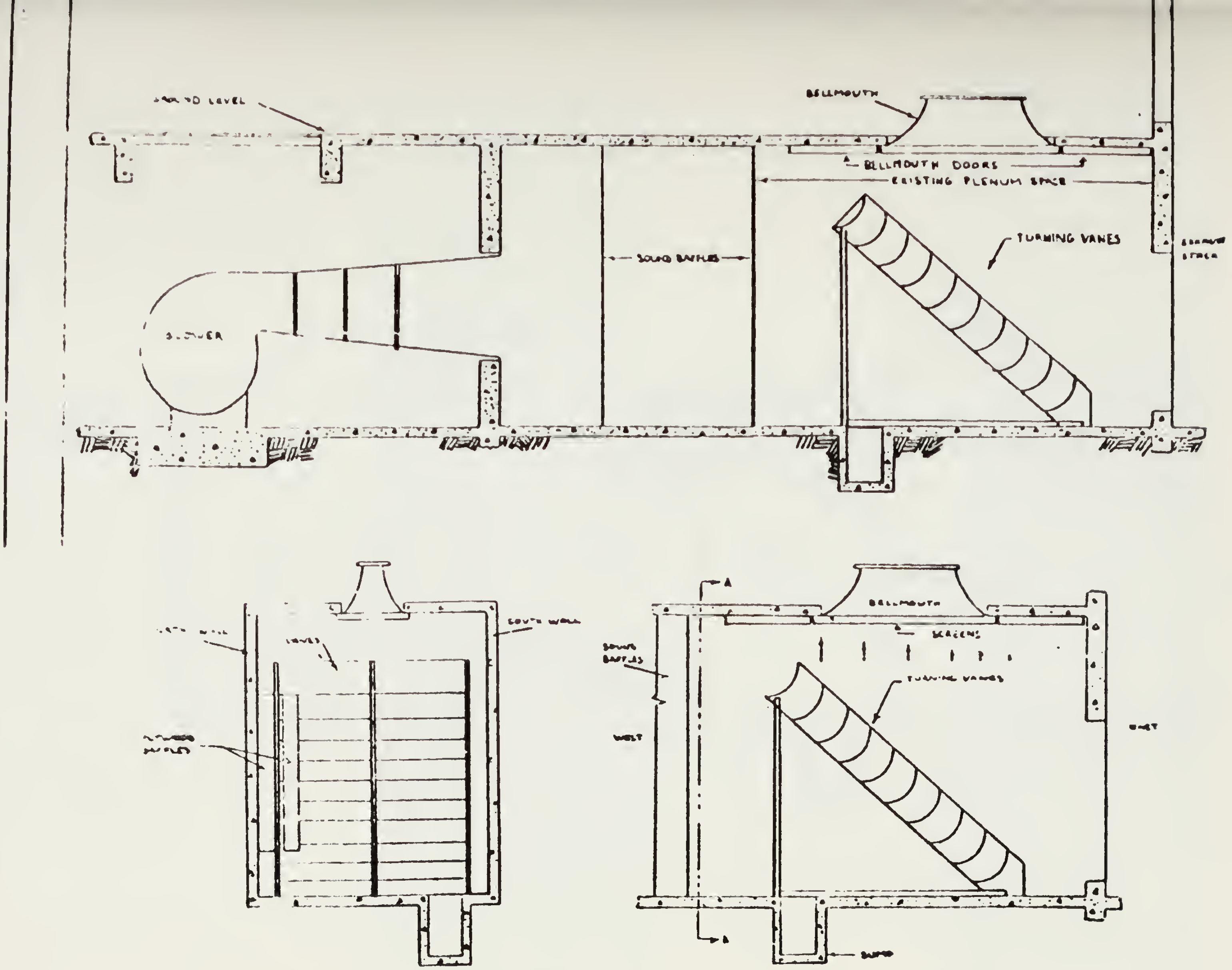


Fig. 2. Plenum Chamber as Modified by Bartocci

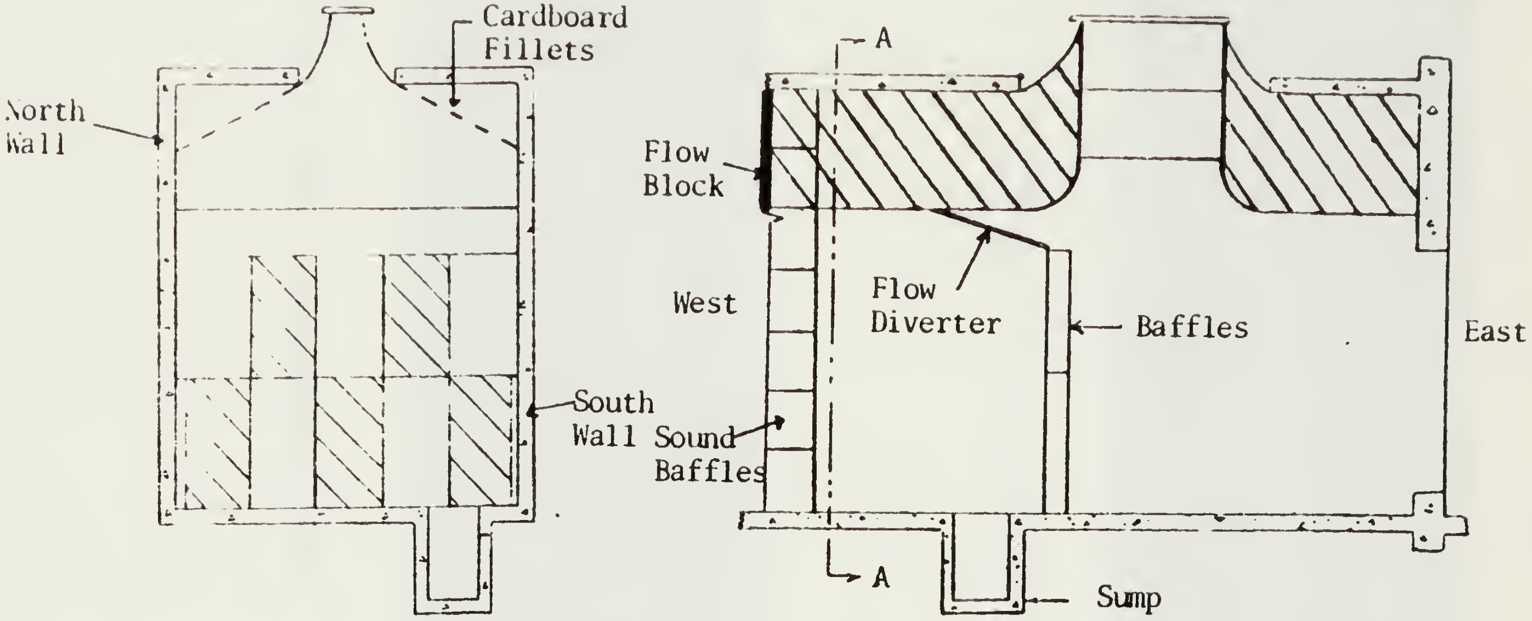


Fig. 3. Plenum Chamber as Modified by Moebius

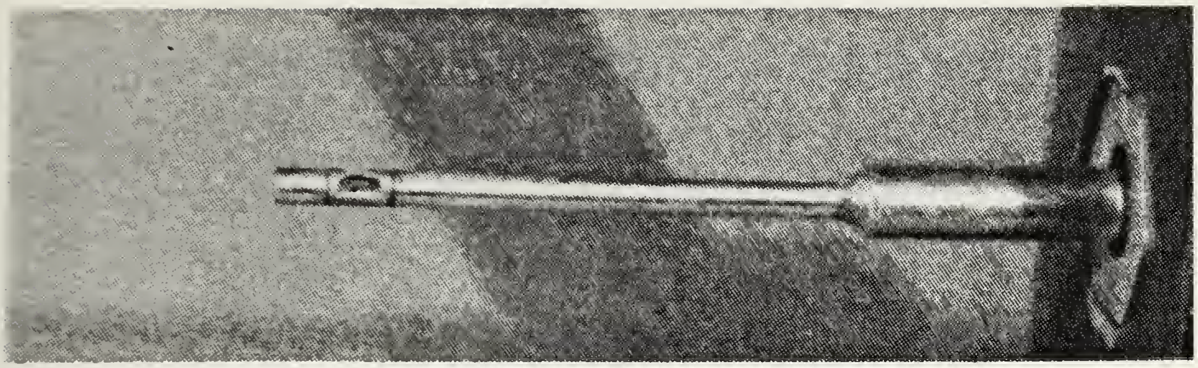


Fig. 4. Lower Plane Survey Probe

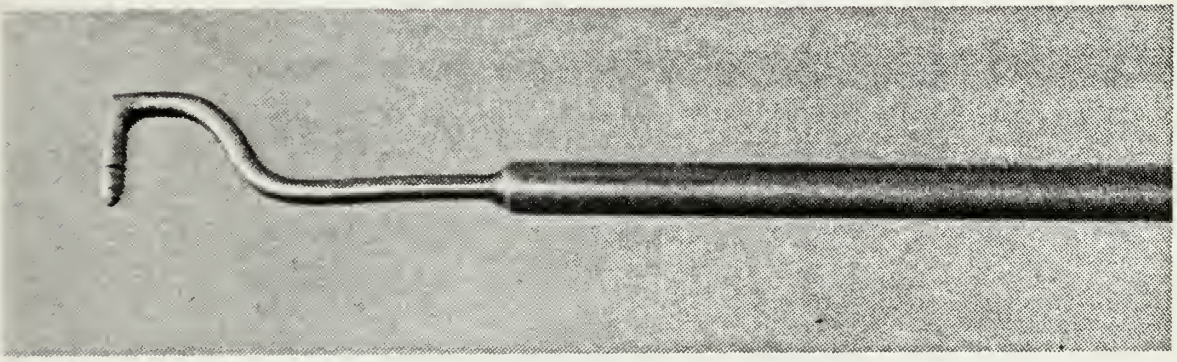


Fig. 5. Upper Plane Survey Probe

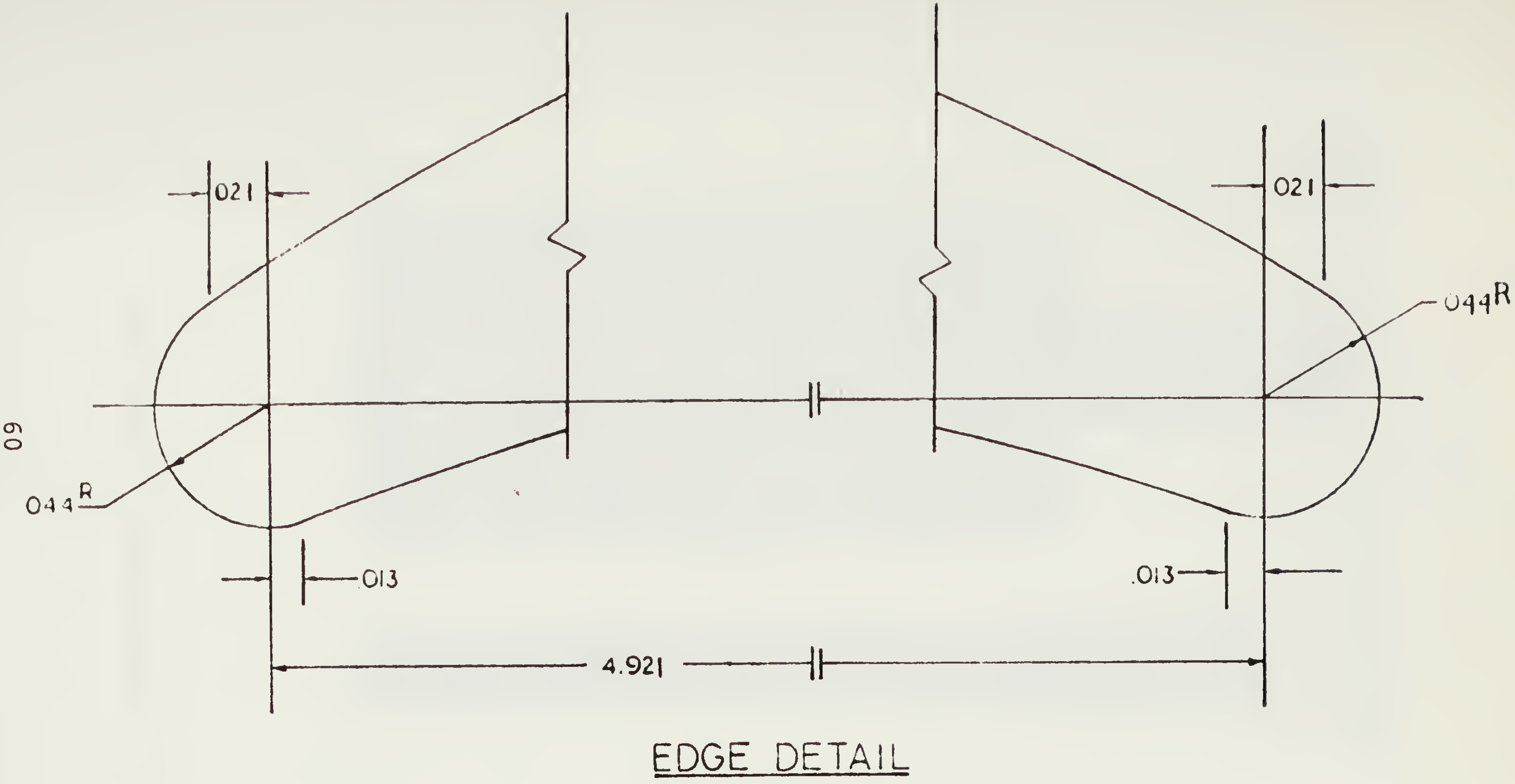


Fig. 6. Blade Edge Detail

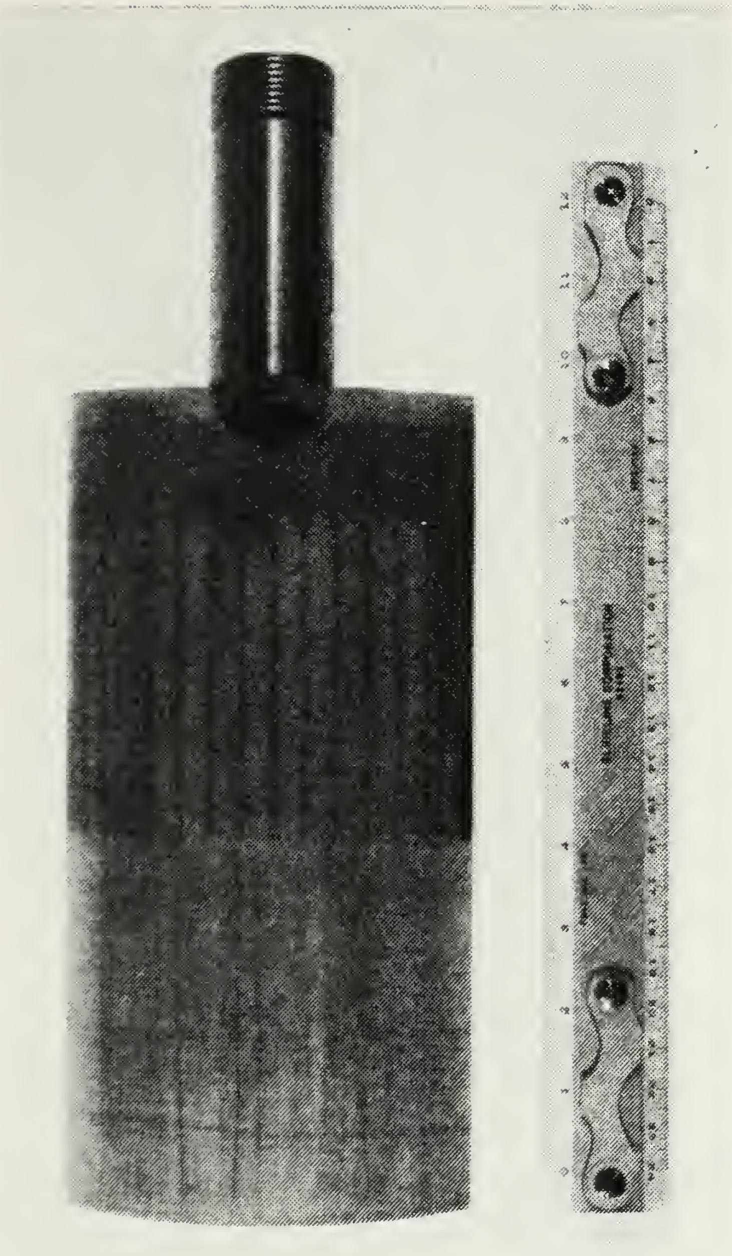


Fig. 7. Photograph of Instrumented Blade

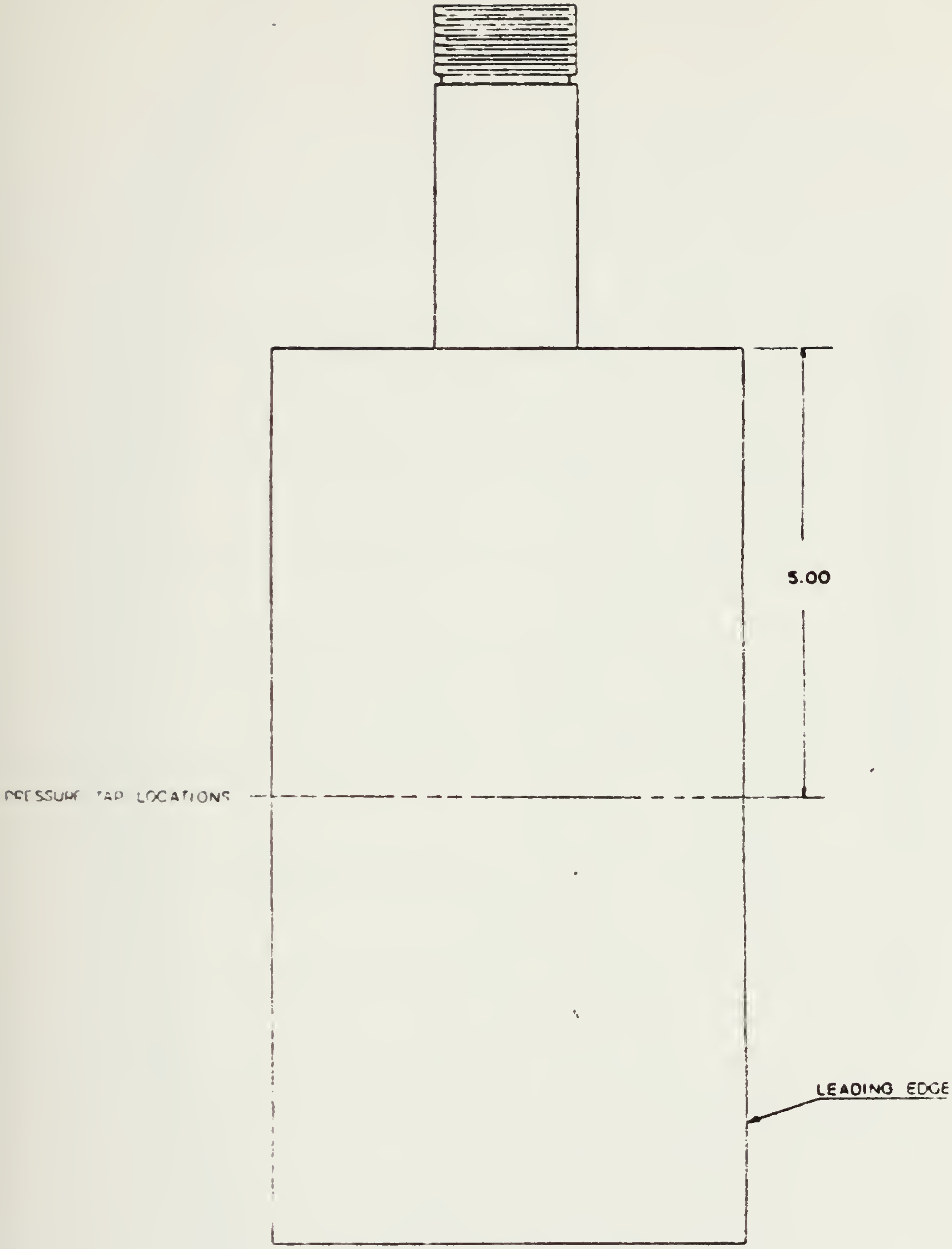


Fig. 8. Instrumented Blade

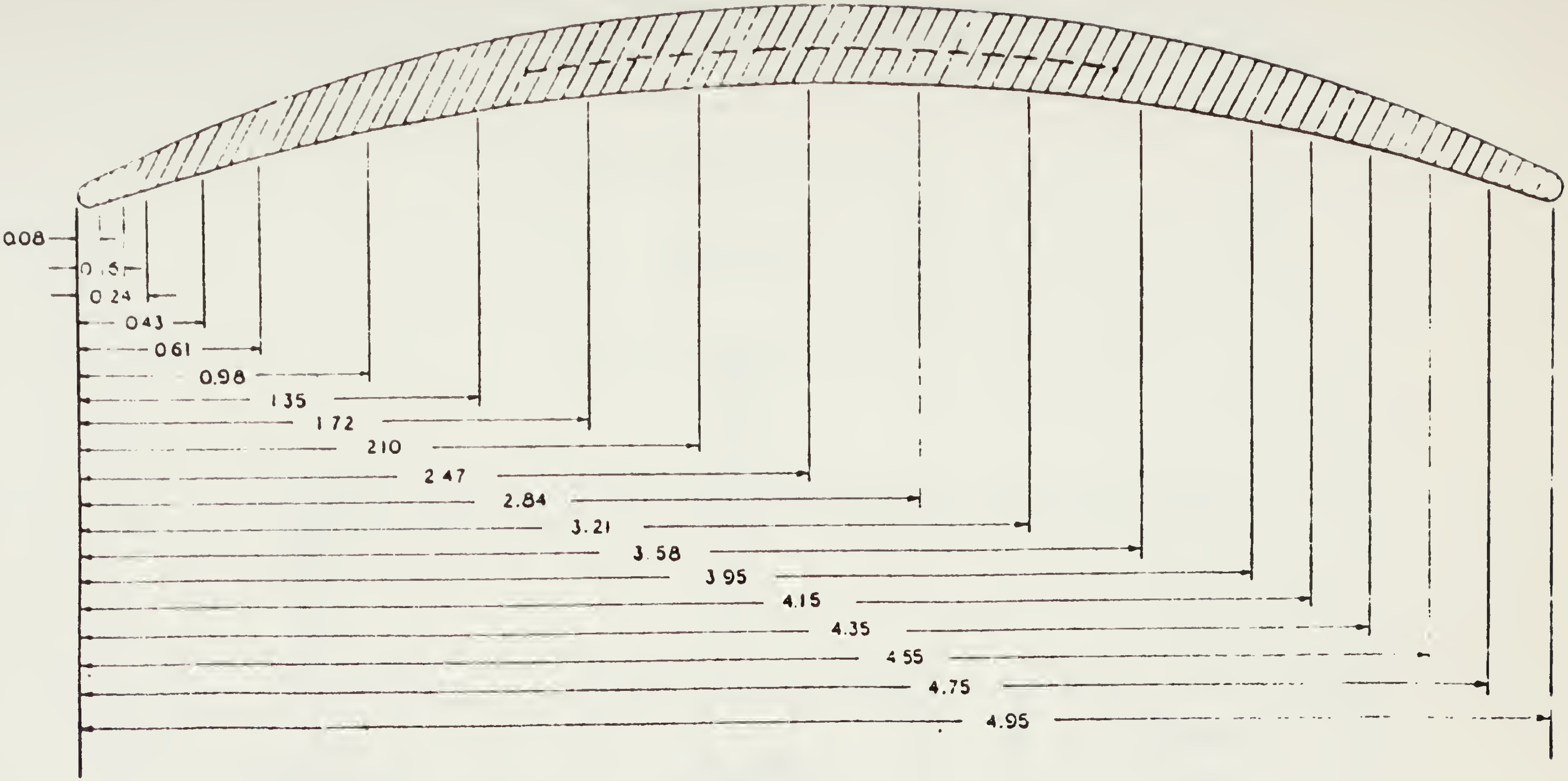


Fig. 9. Instrumented Blade Tap Locations

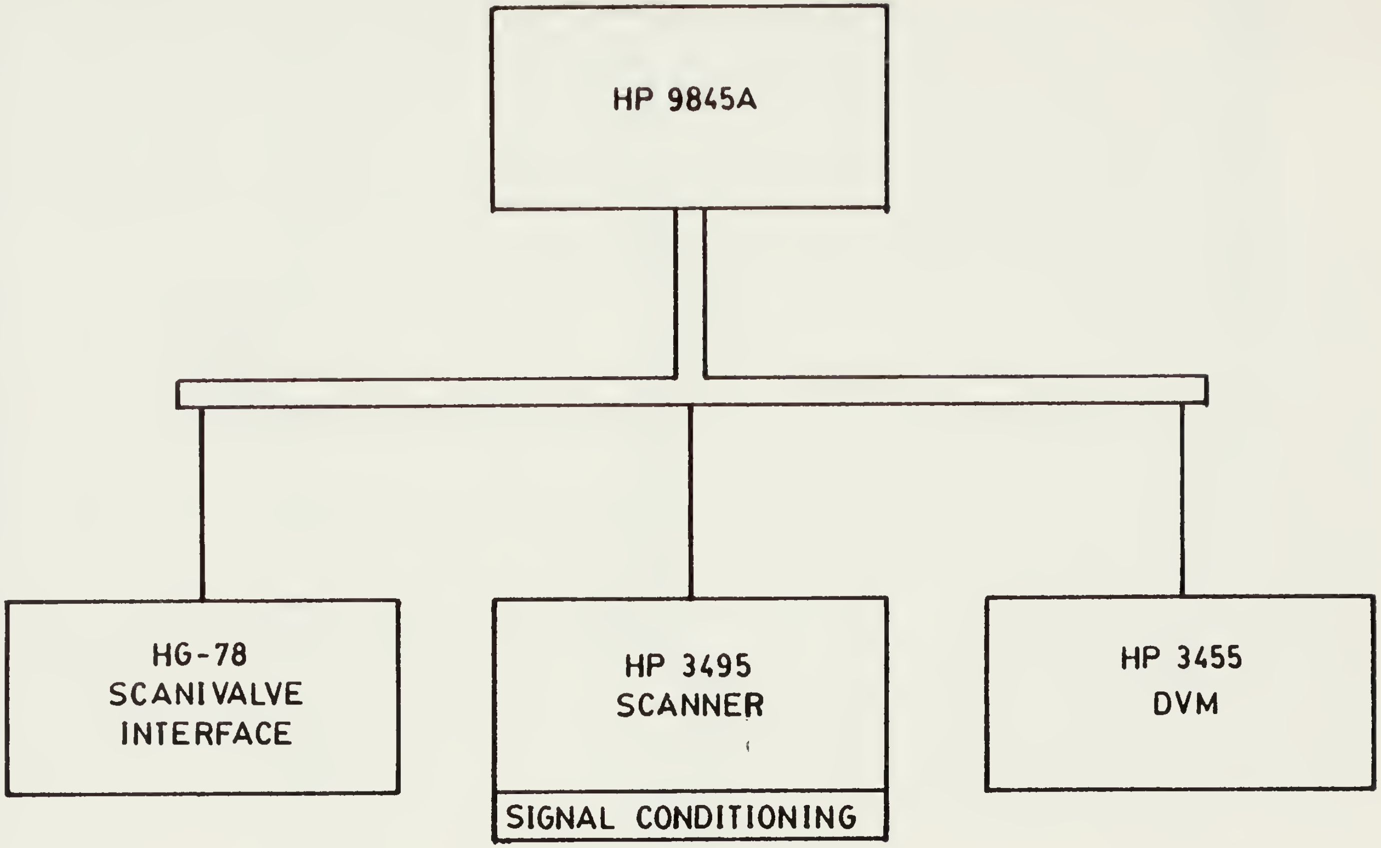


Fig. 10. Data Acquisition System

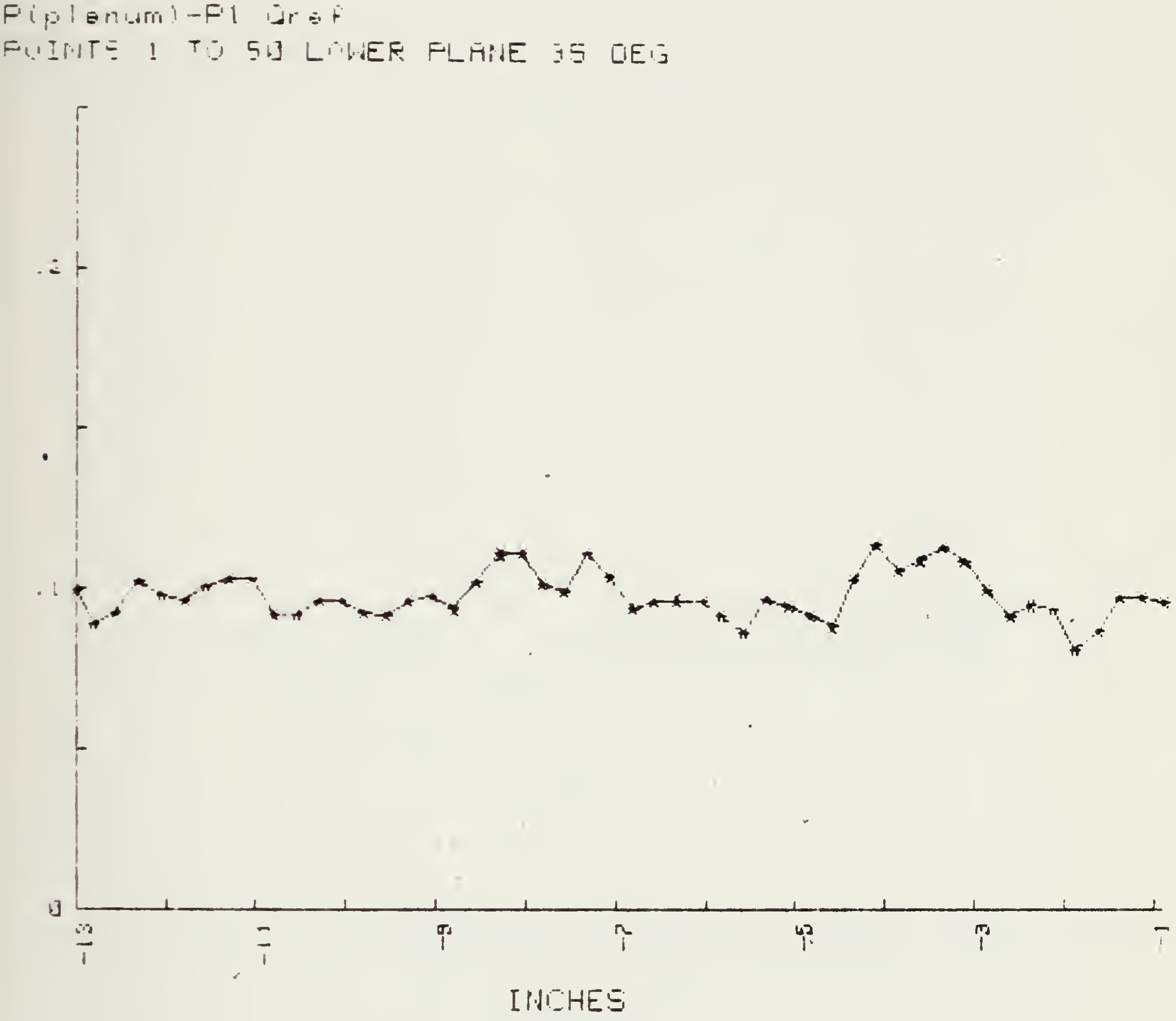


Fig. 11. Probe survey Data at Midspan of Lower Plane End Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

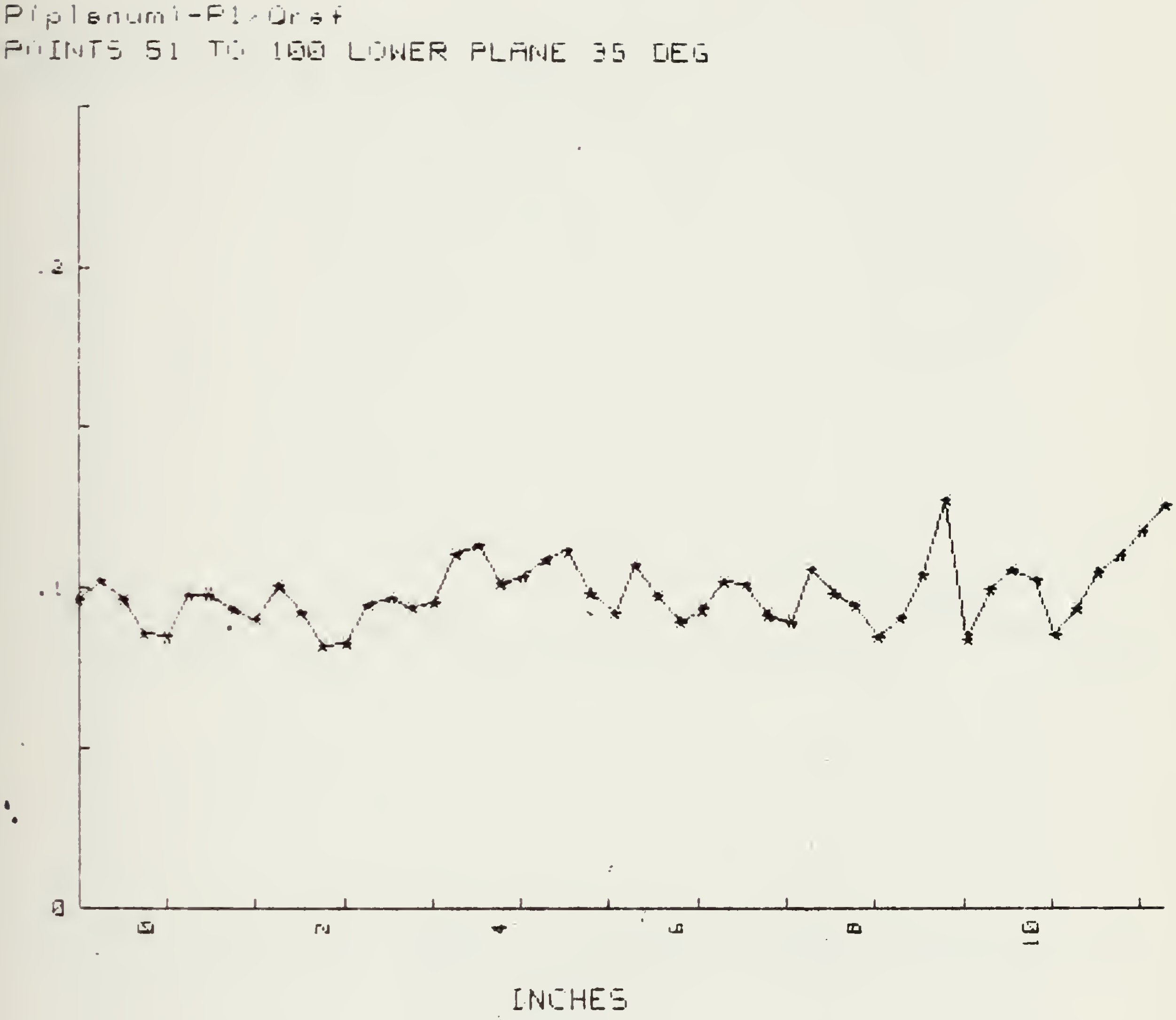


Fig. 12. Probe Survey Data at Midspan of Lower Plane End Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

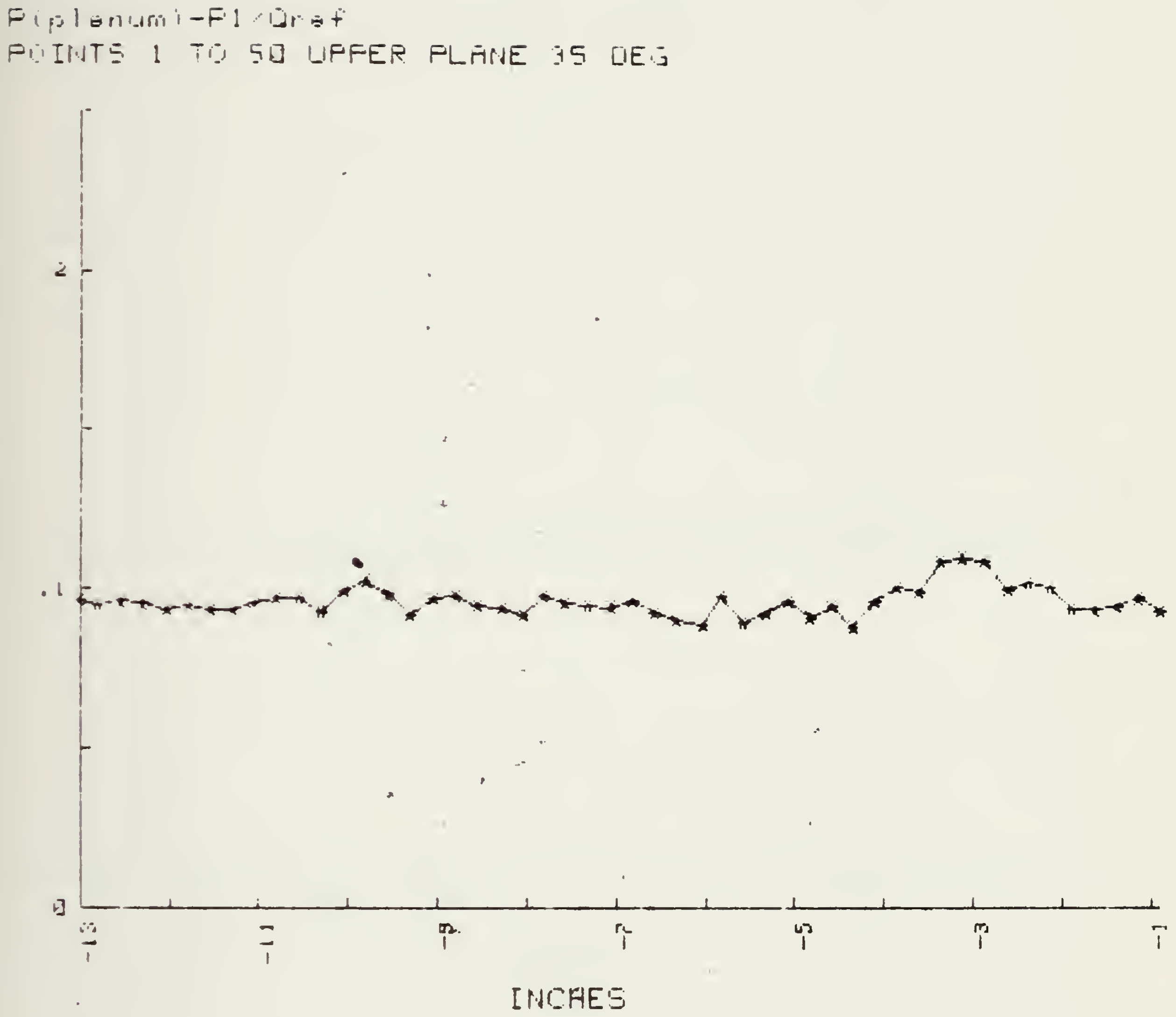


Fig. 13. Probe Survey Data at Midspan of Upper Plane End Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

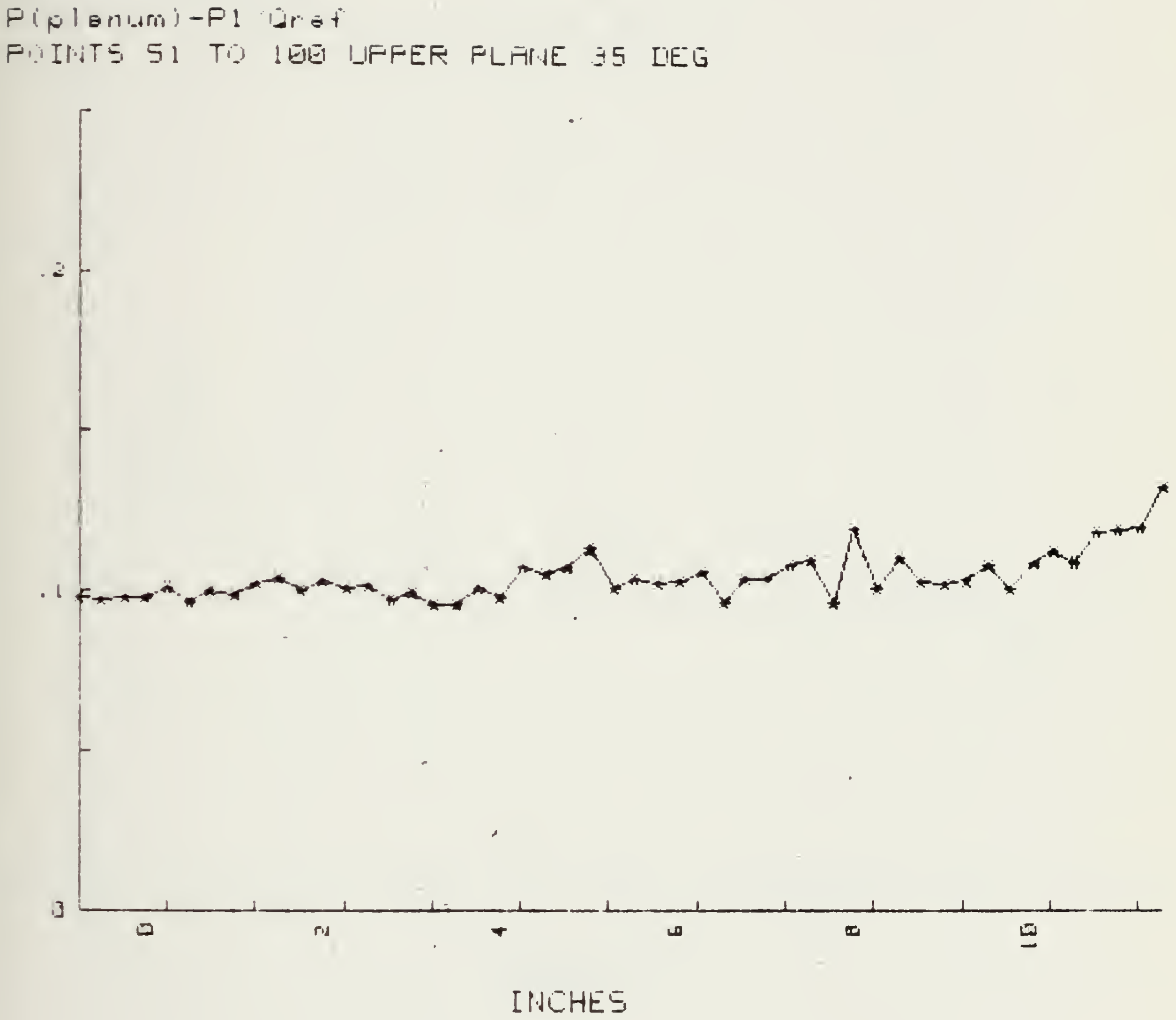


Fig. 14. Probe Survey Data at Midspan of Upper Plane End Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

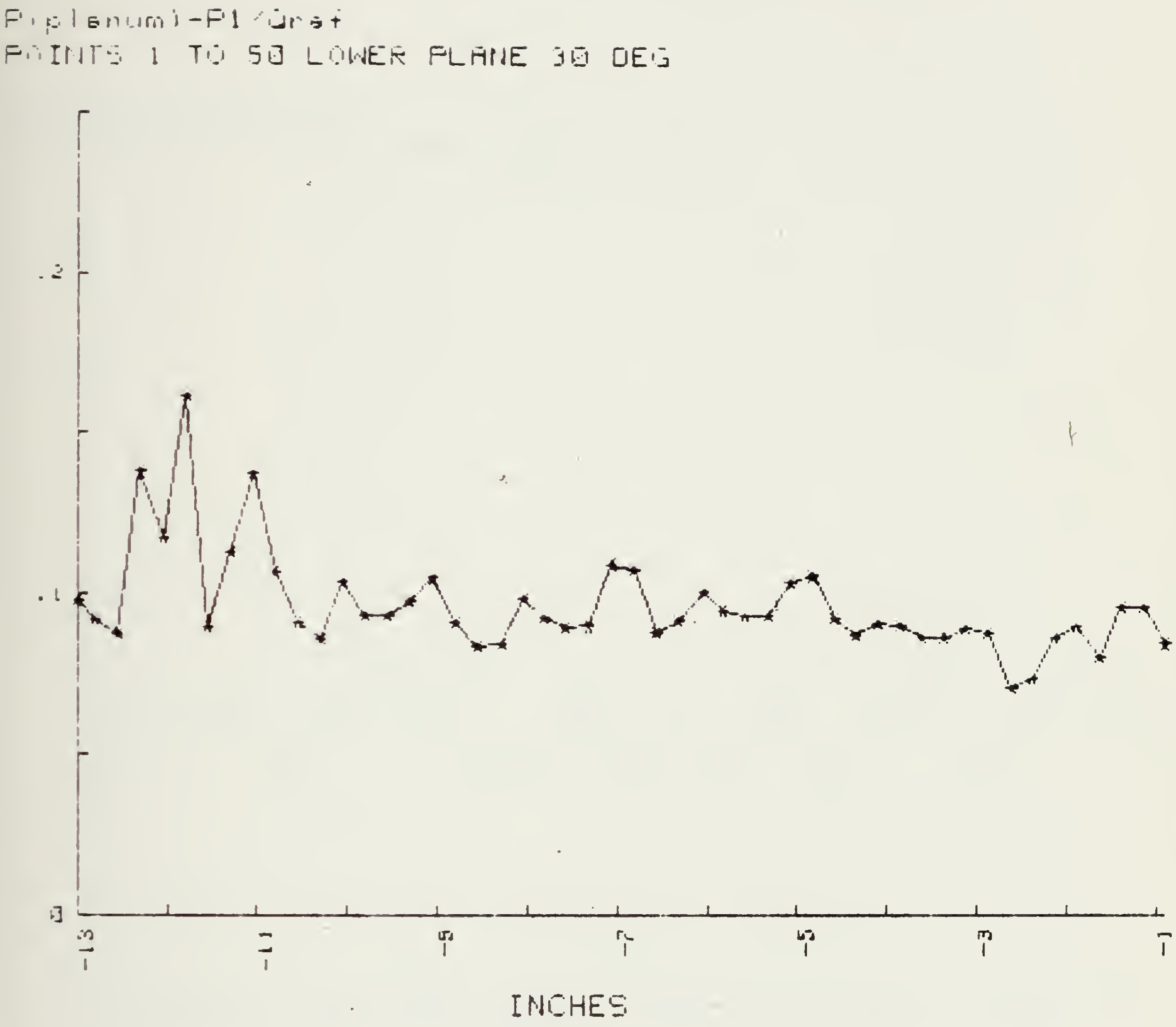


Fig. 15. Probe Survey Data at Midspan of Lower Plane End Walls at 30°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

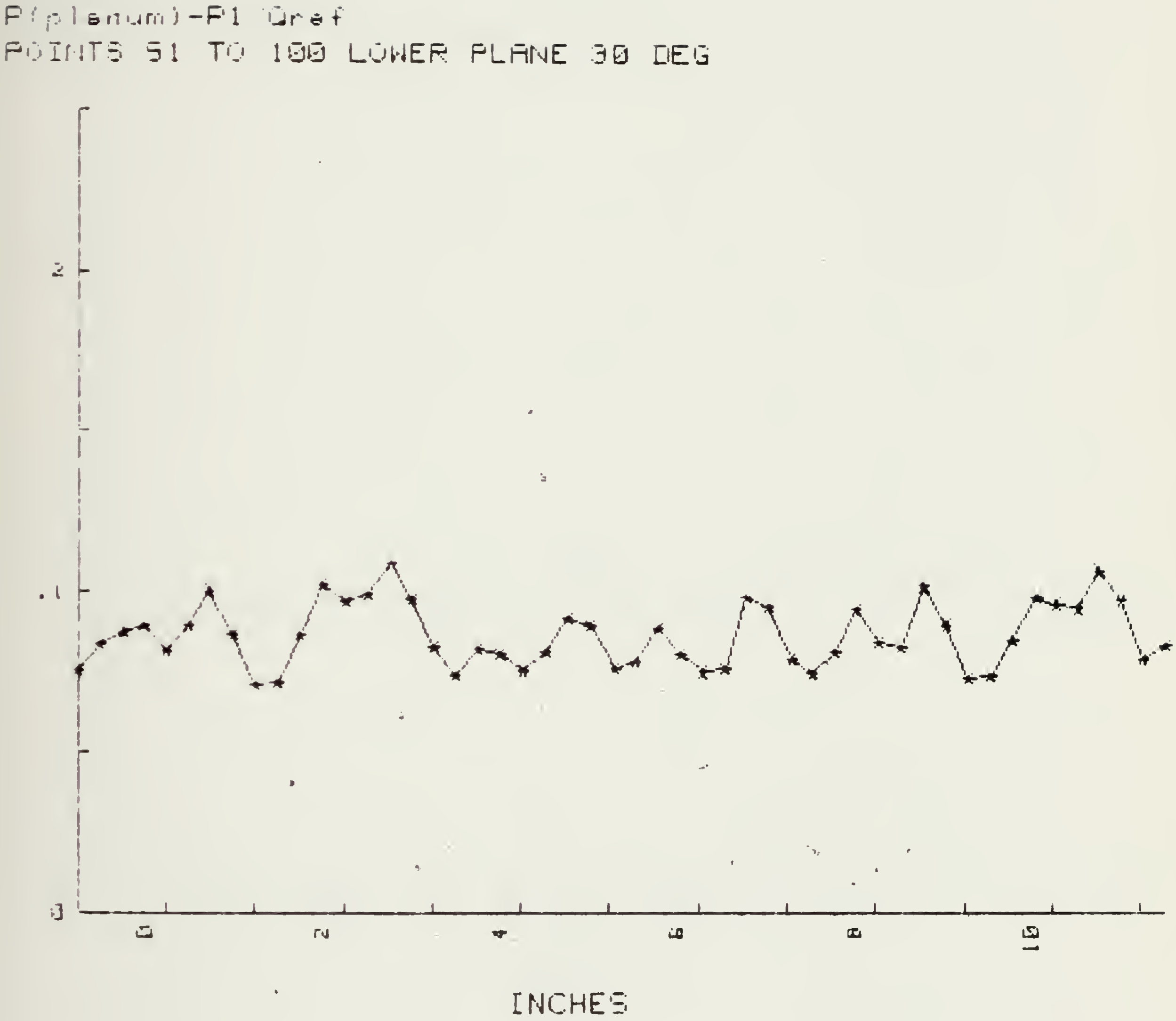


Fig. 16. Probe Survey Data at Midspan of Lower Plane End Walls at 30°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

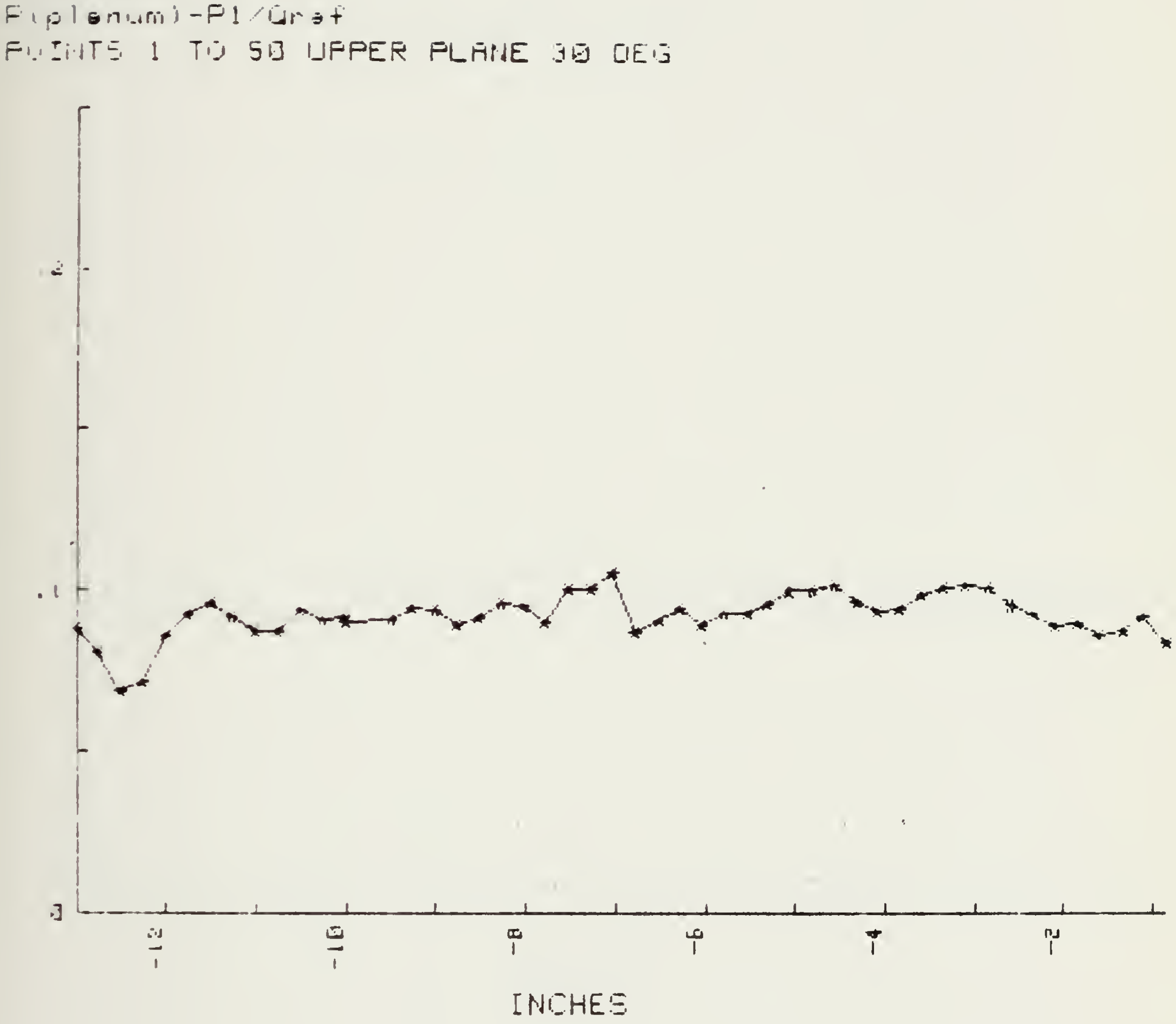


Fig. 17. Probe Survey Data at Midspan of Upper Plane End Walls at 30°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

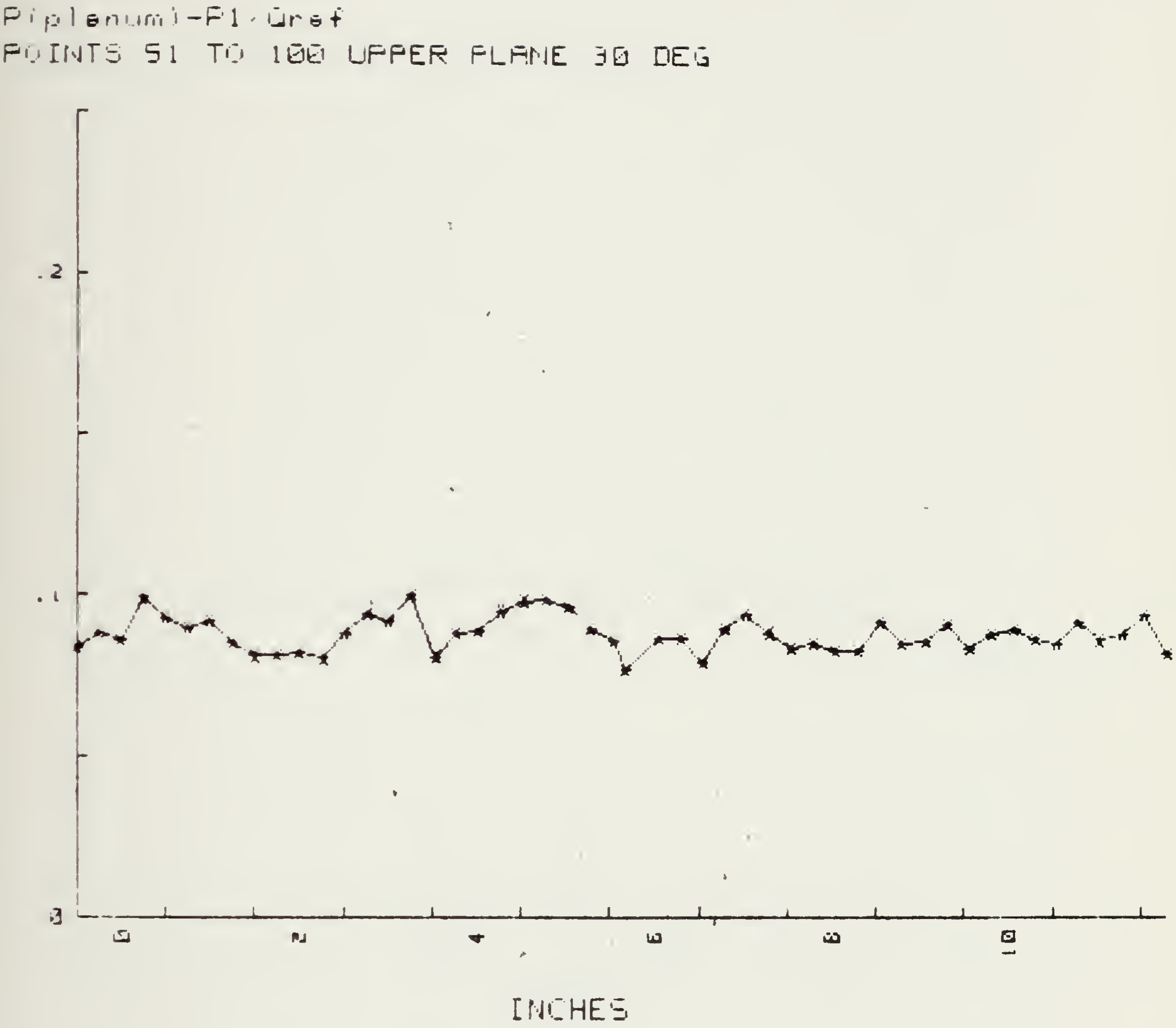


Fig. 18. Probe Survey Data at Midspan of Upper Plane End Walls at 30°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

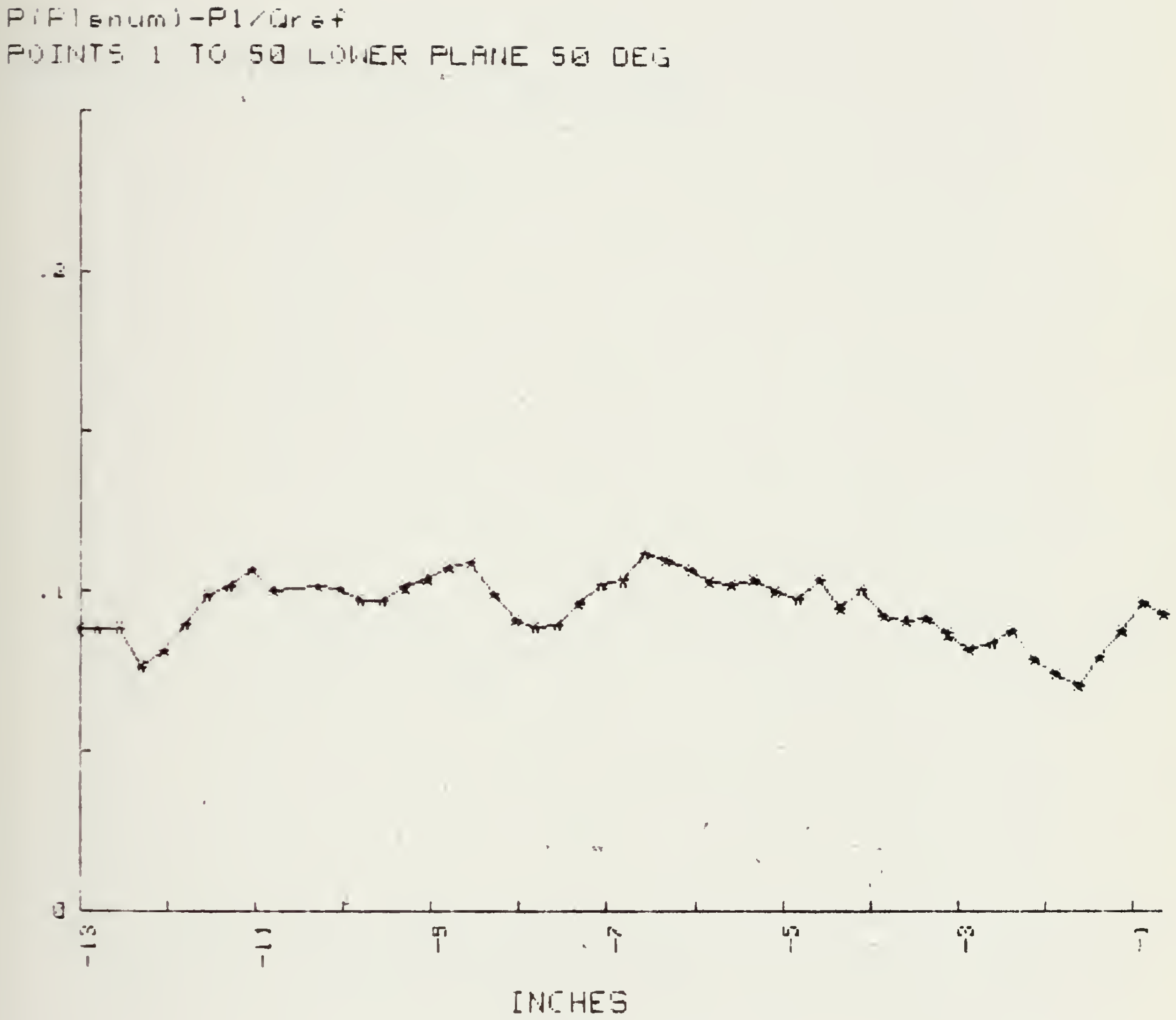


Fig. 19. Probe Survey Data at Midspan of Lower Plane End Walls at 50°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

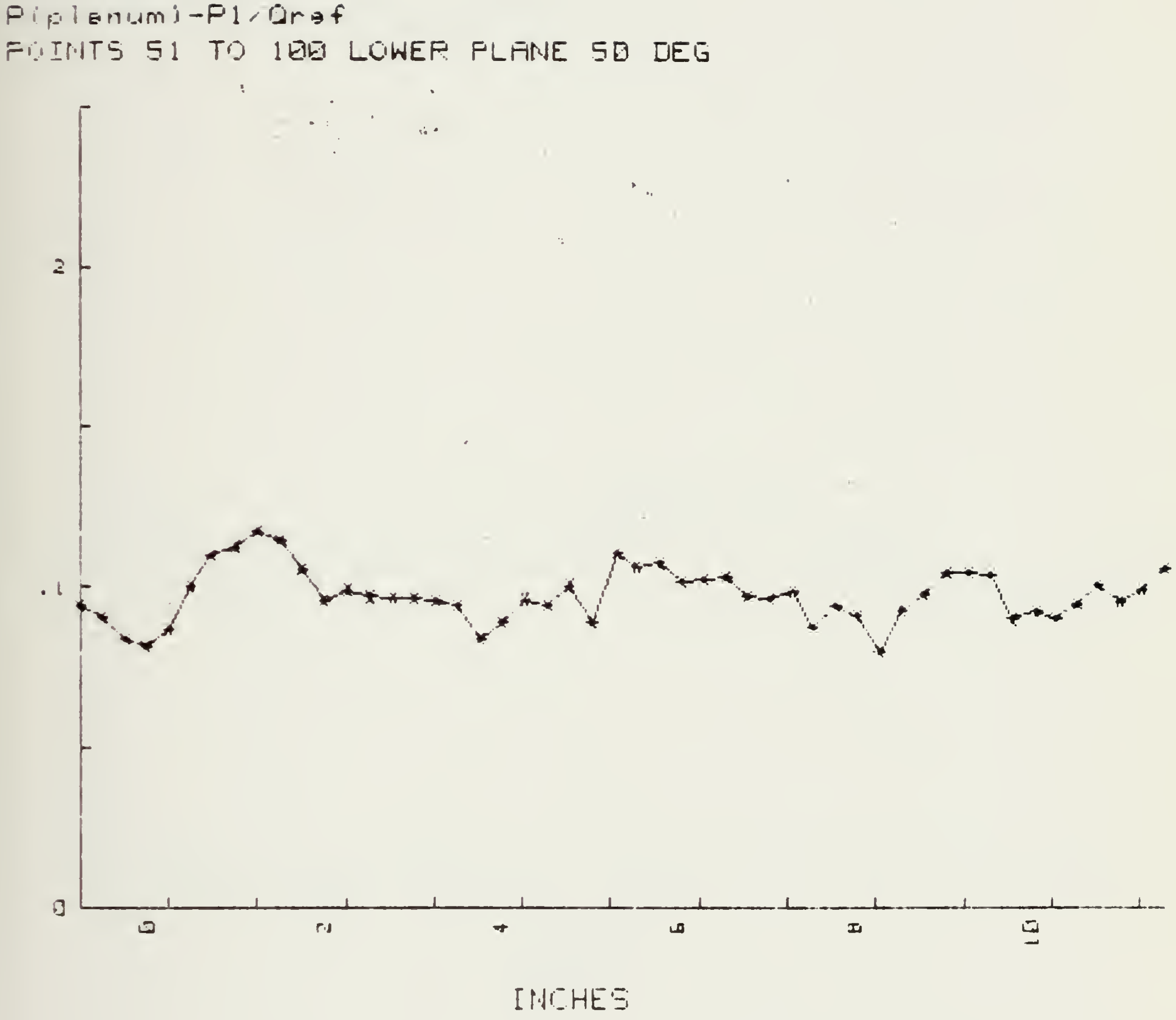


Fig. 20. Probe Survey Data at Midspan of Lower Plane End Walls at 50°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

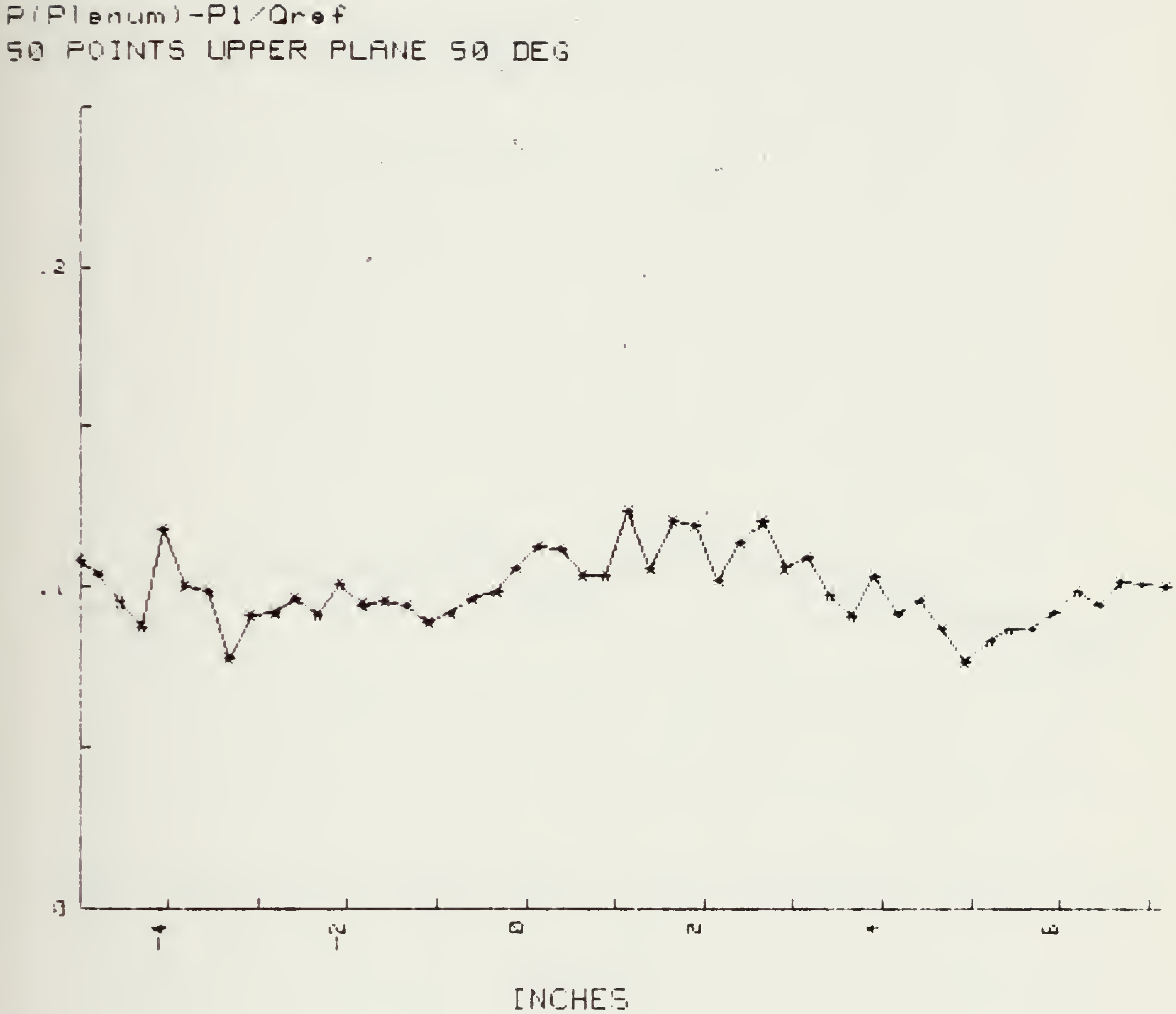


Fig. 21. Probe Survey Data at Midspan of Upper Plane End Walls at 50° $(P_{PLENUM} - P_t)/Q_{ref}$

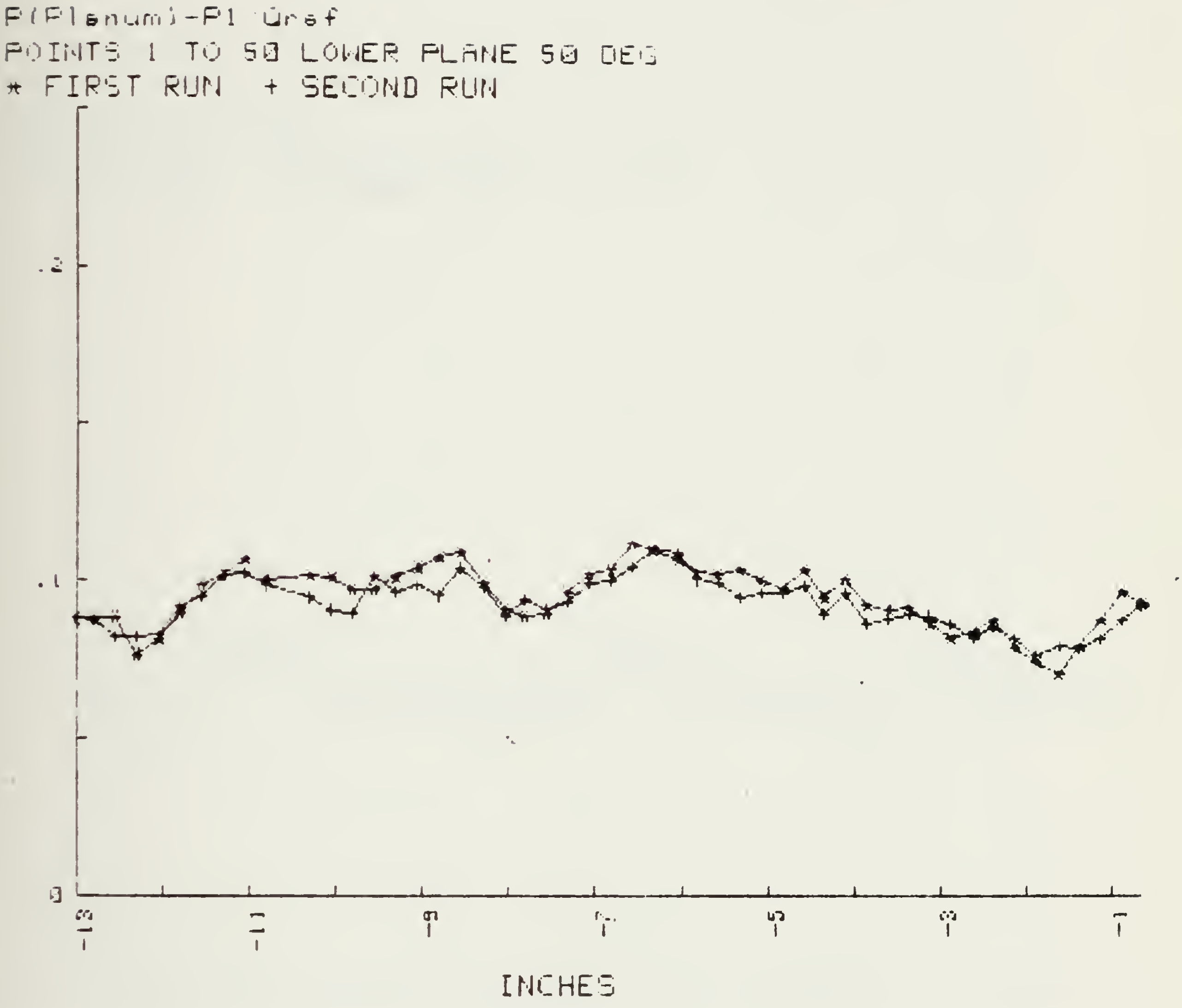


Fig. 22. Probe Survey Data at Midspan at Lower Plane End Walls at 50°, Two Runs, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

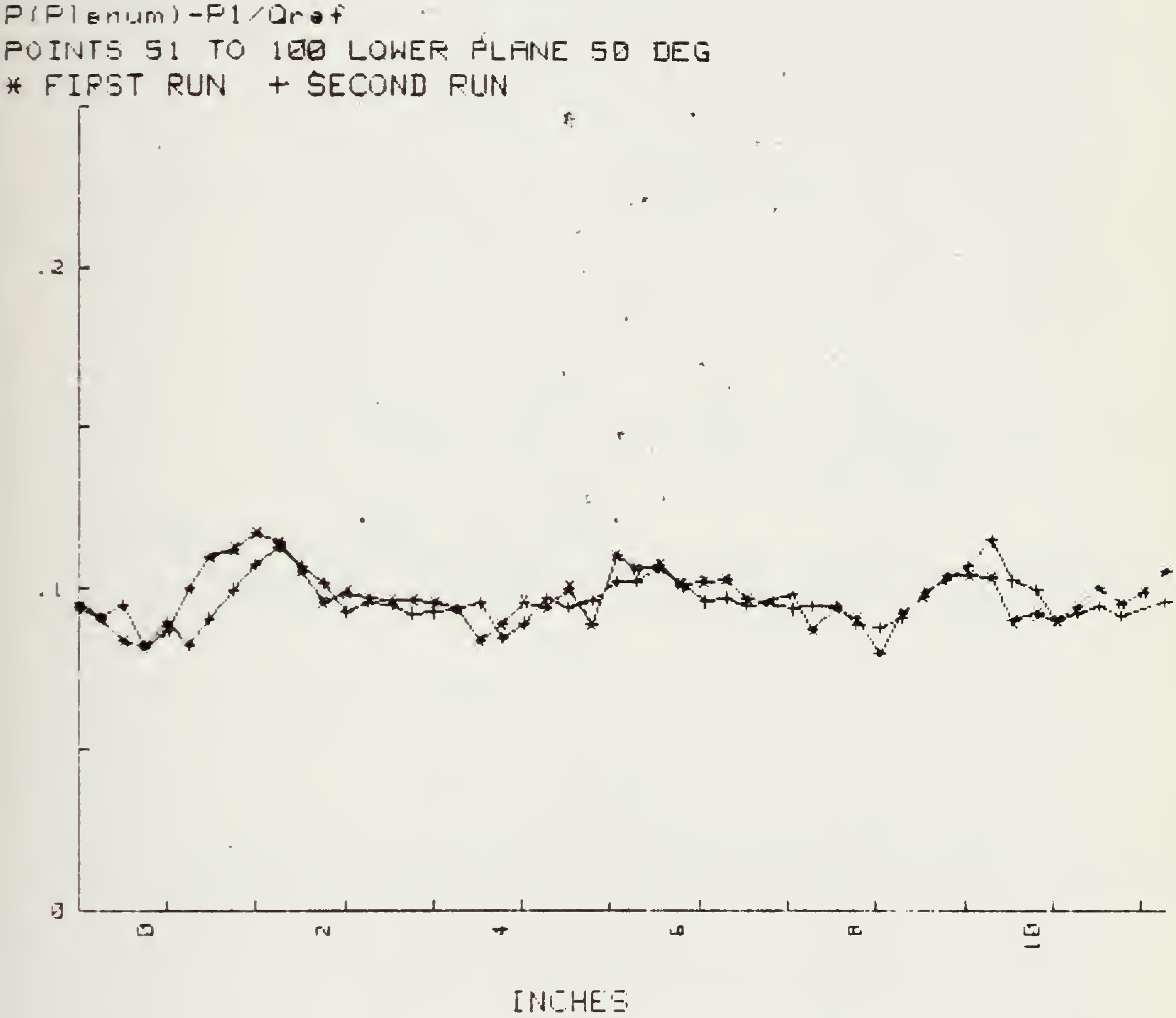


Fig. 23. Probe Survey Data at Midspan at Lower Plane End Walls at 50°, Two Runs, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

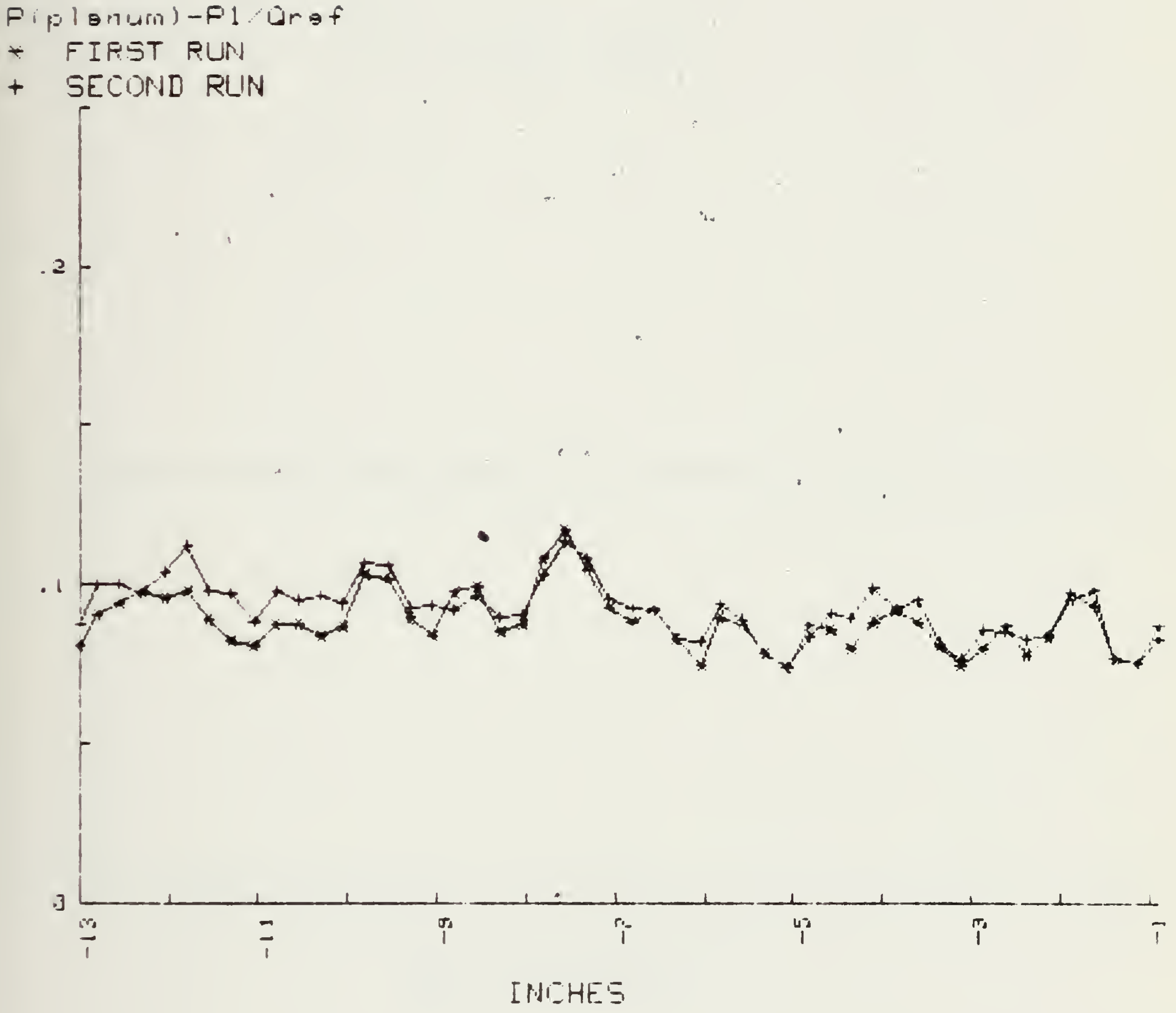


Fig. 24. Probe Survey Data at Midspan at Lower Plane End Walls at 30°, Two Runs, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

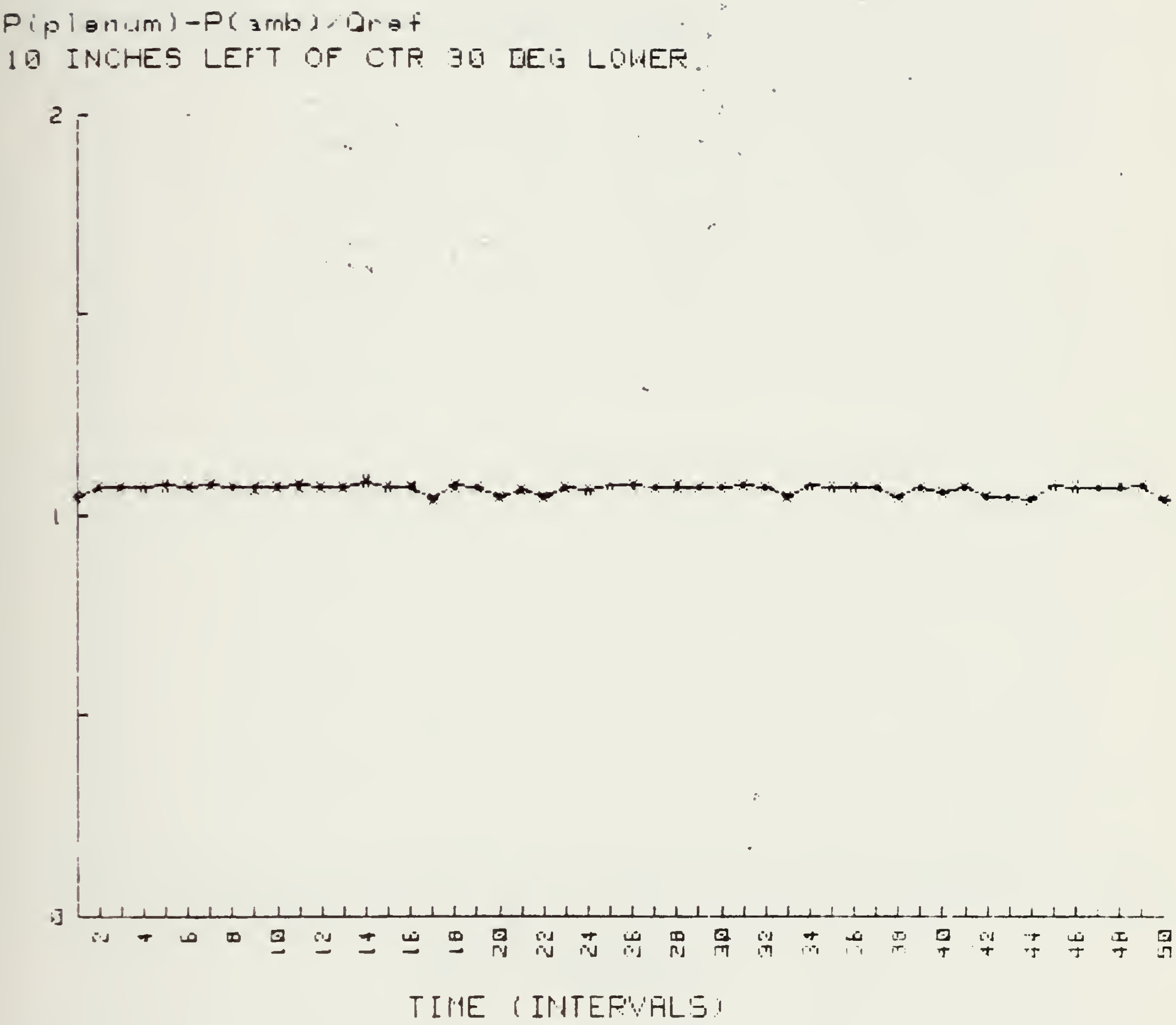


Fig. 25. Repetitive Samples with Fixed Probe Position (10" Left of CTR Midspan, End Walls 30°, Lower Plane $(P_{PLENUM} - P_{AMB})/Q_{ref}$)

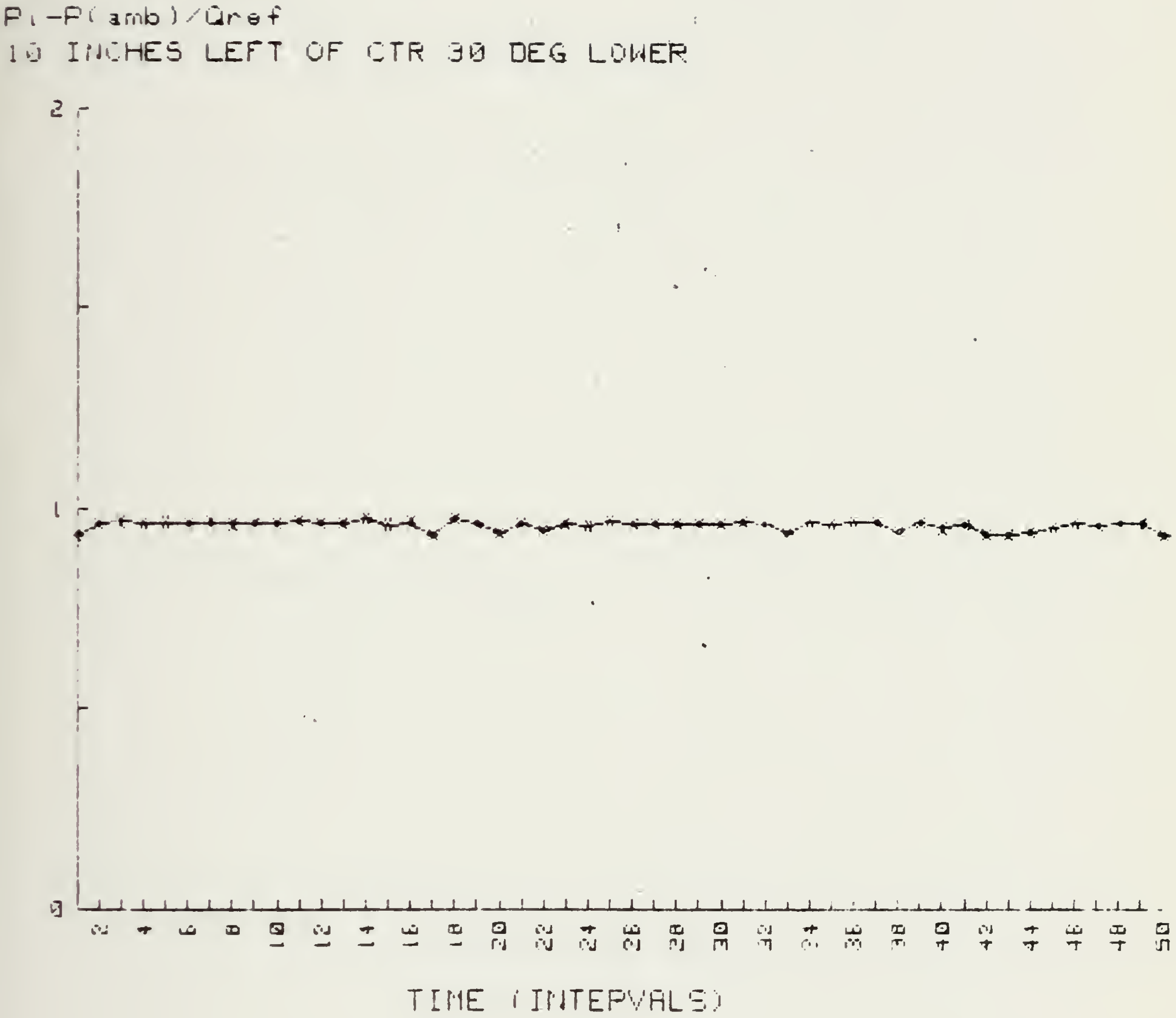


Fig. 26. Repetitive Samples with Fixed Probe Position (10" Left of CTR Midspan, End Walls at 30°, Lower Plane $(P_t - P_{AMB})/Q_{ref}$)

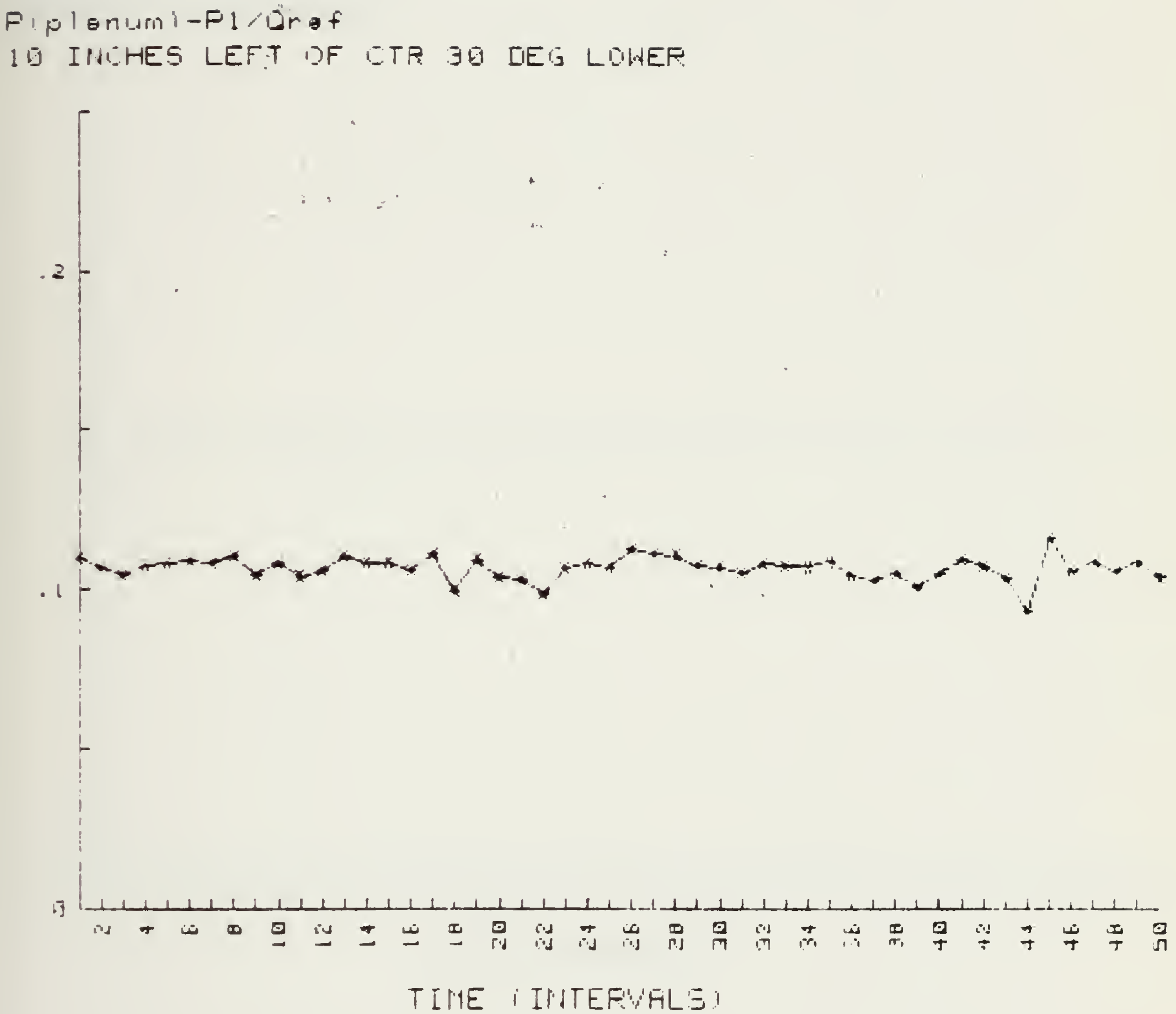


Fig. 27. Repetitive Samples with Fixed Probe Position (10" Left of CTR Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_t)/Q_{ref}$

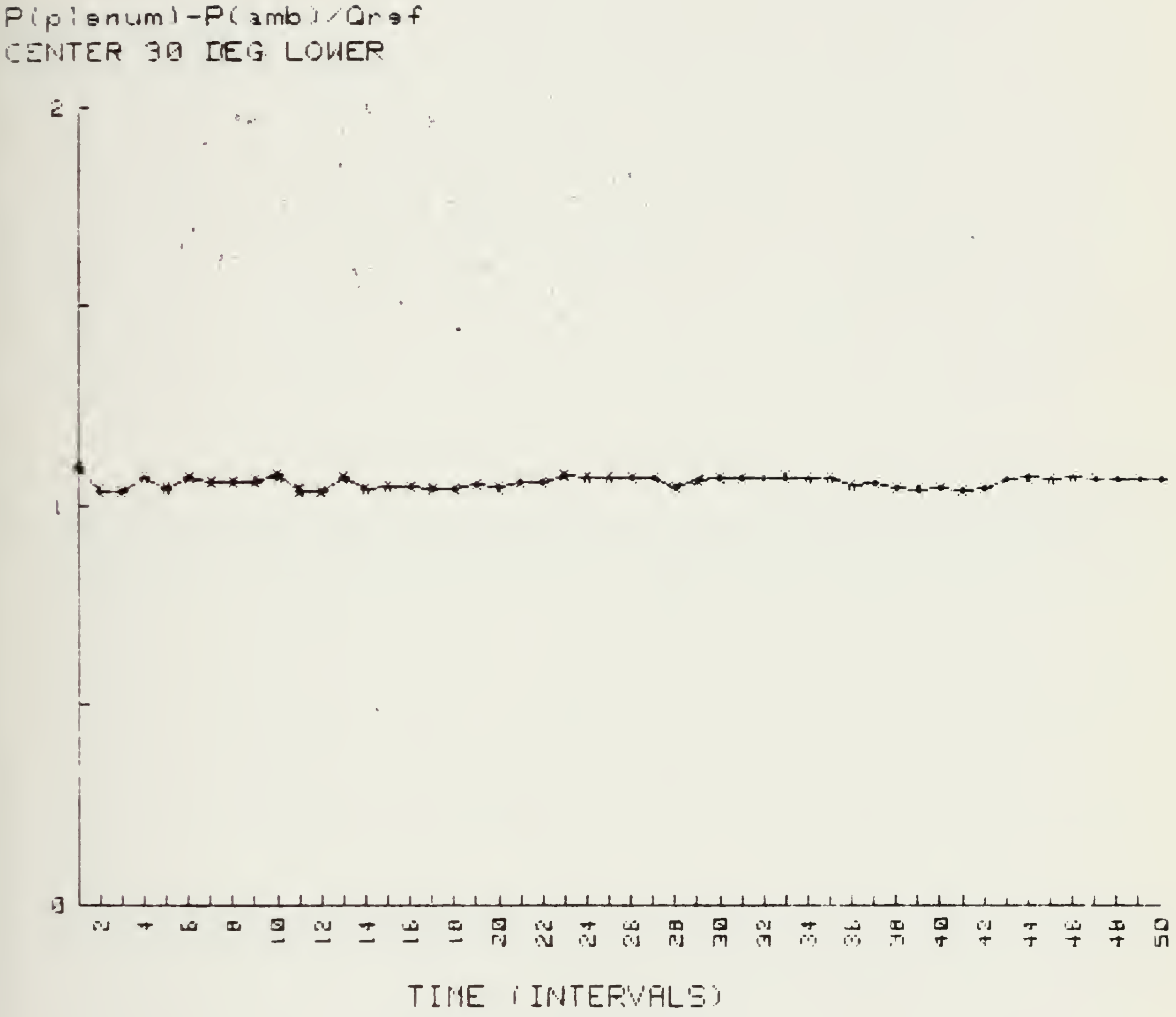


Fig. 28. Repetitive Samples with Fixed Probe Position (on Centerline at Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_{AMB})/Q_{ref}$)

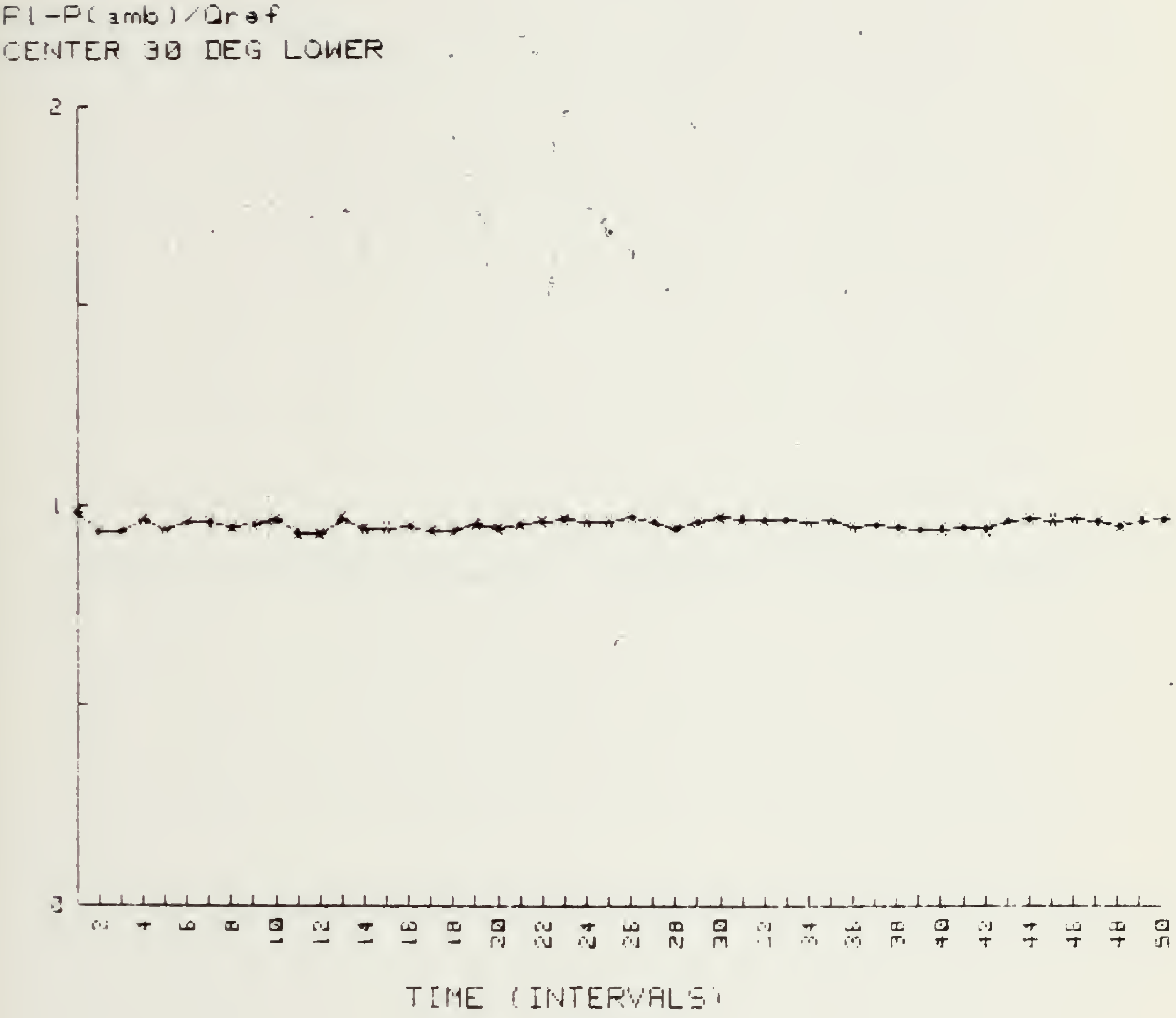


Fig. 29. Repetitive Samples with Fixed Probe Position (on Centerline at Midspan, End Walls at 30°, Lower Plane $(P_t - P_{AMB})/Q_{ref}$)

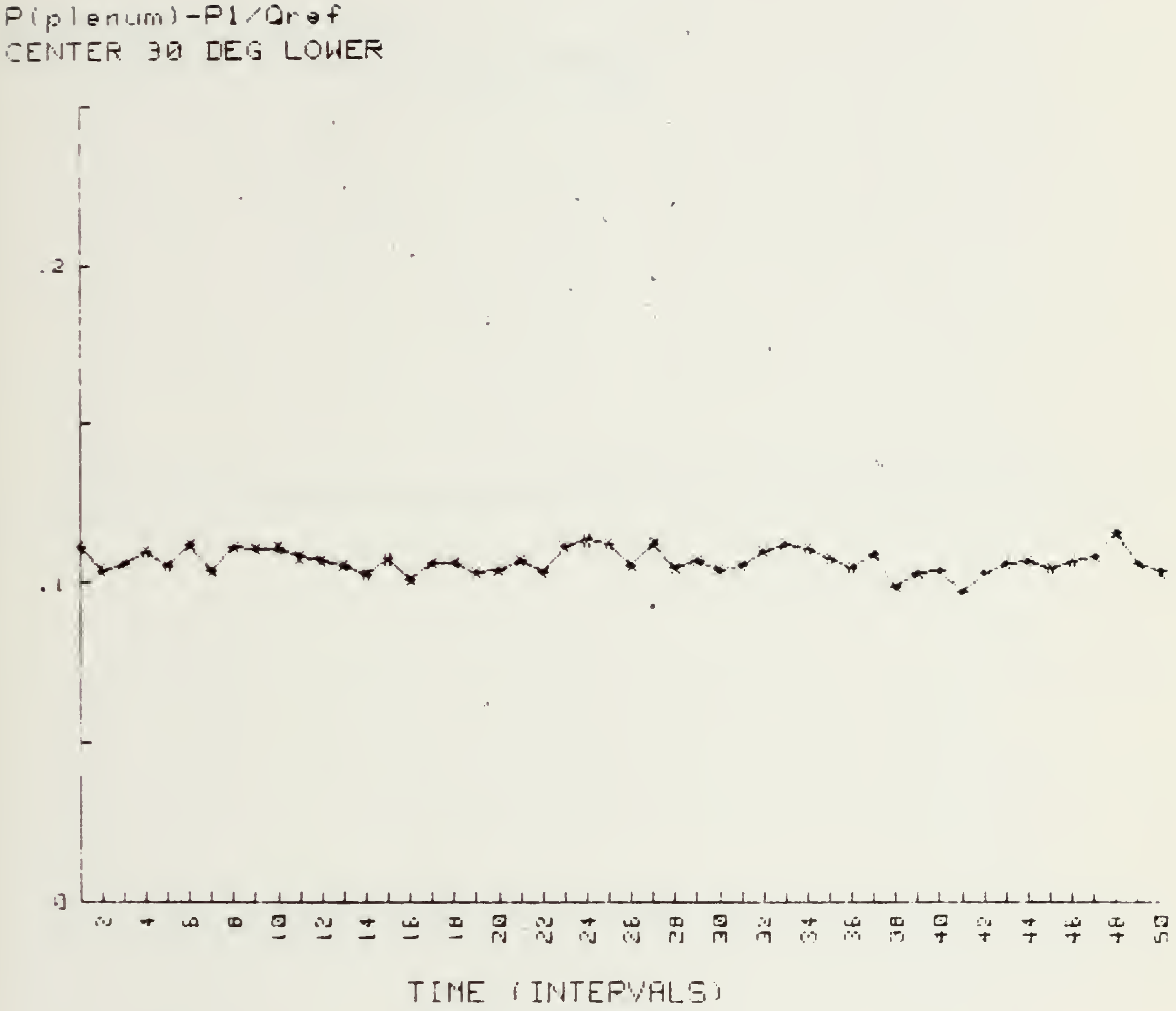


Fig. 30. Repetitive Samples with Fixed Probe Position (on Centerline at Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_t)/Q_{ref}$)

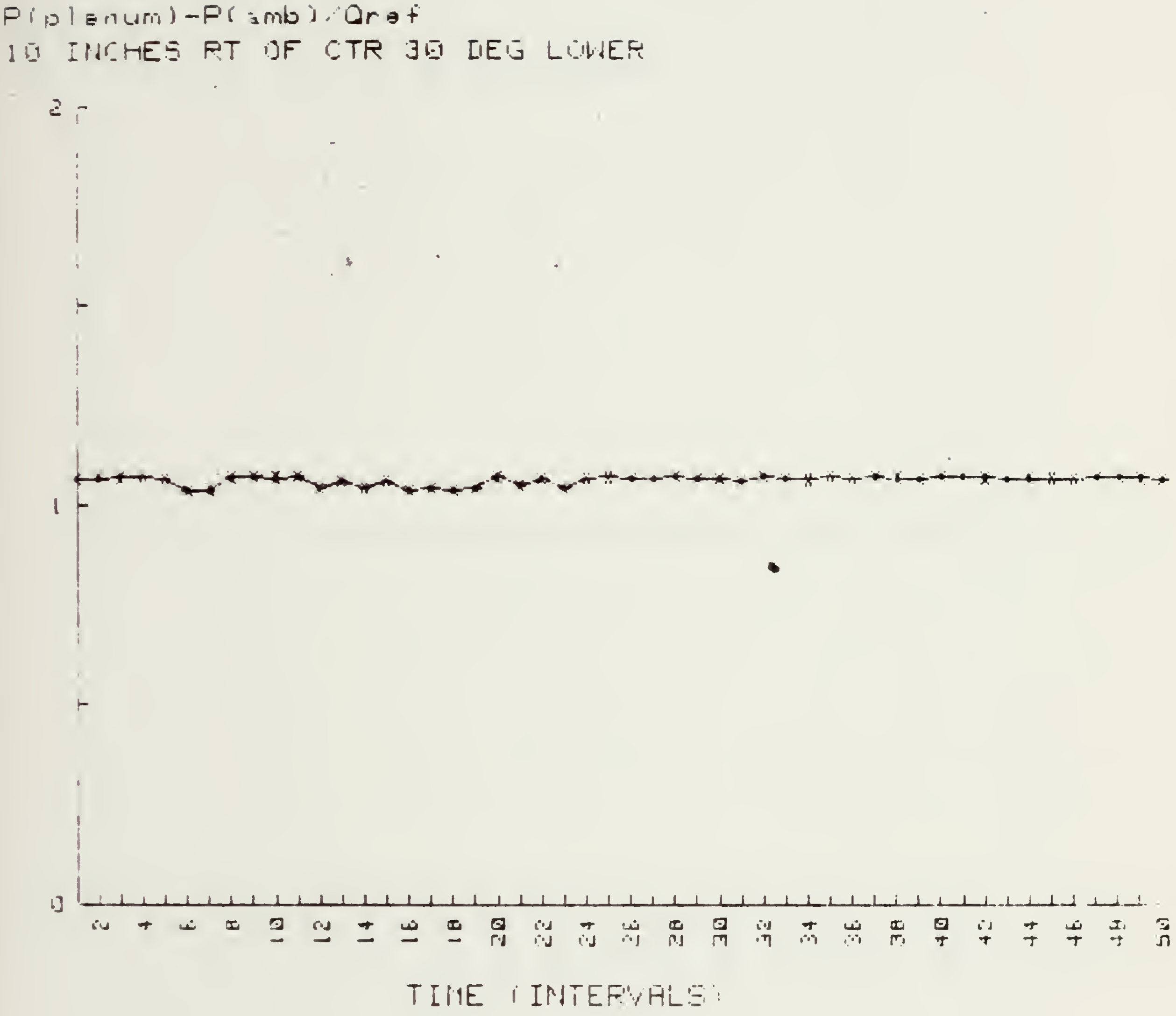


Fig. 31. Repetitive Samples with Fixed Probe Position (10" Right of CTR Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_{AMB})/Q_{ref}$)

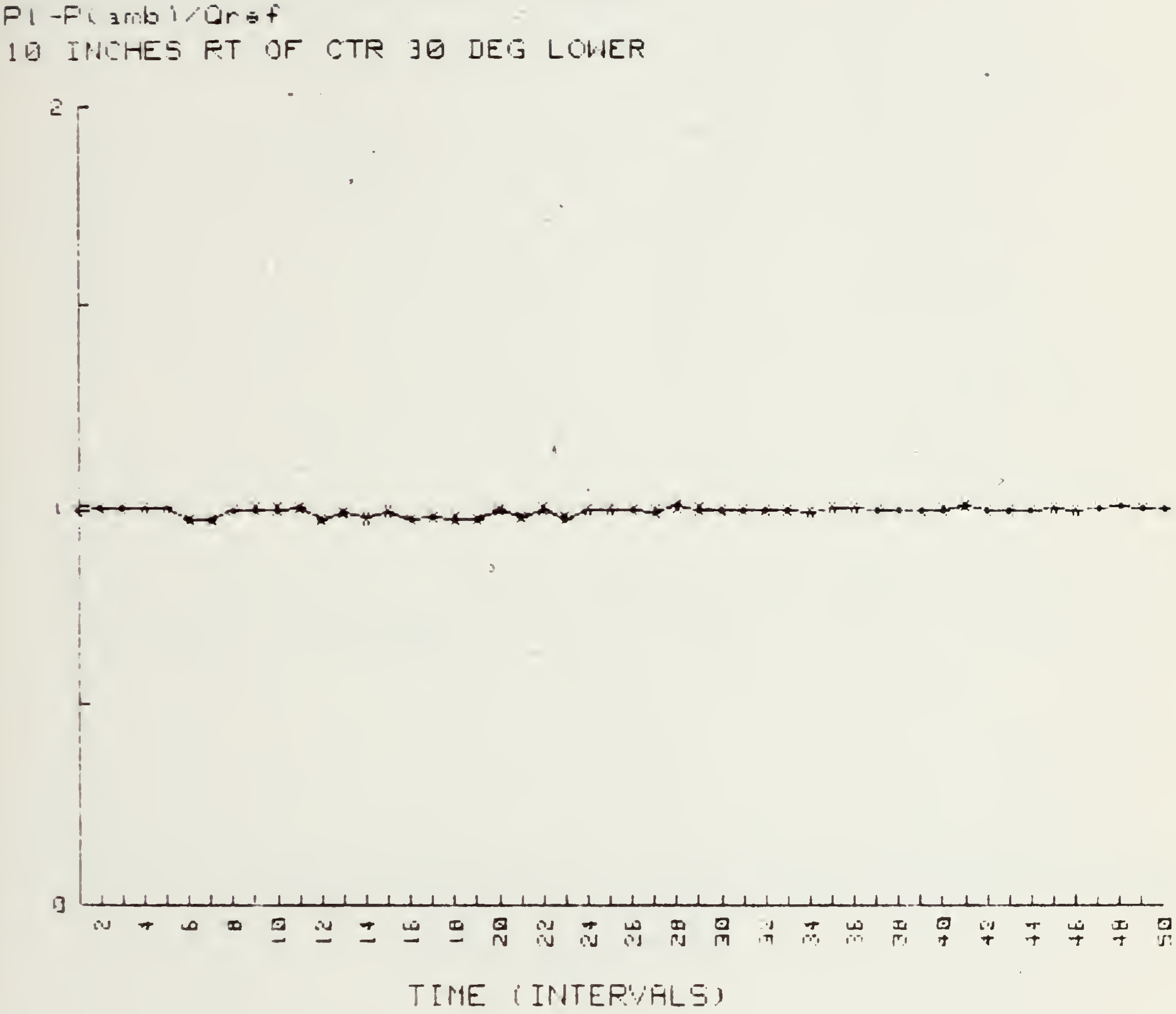


Fig. 32. Repetitive Samples with Fixed Probe Position (10" Right of CTR Midspan, End Walls at 30°, Lower Plane $(P_t - P_{AMB})/Q_{ref}$)

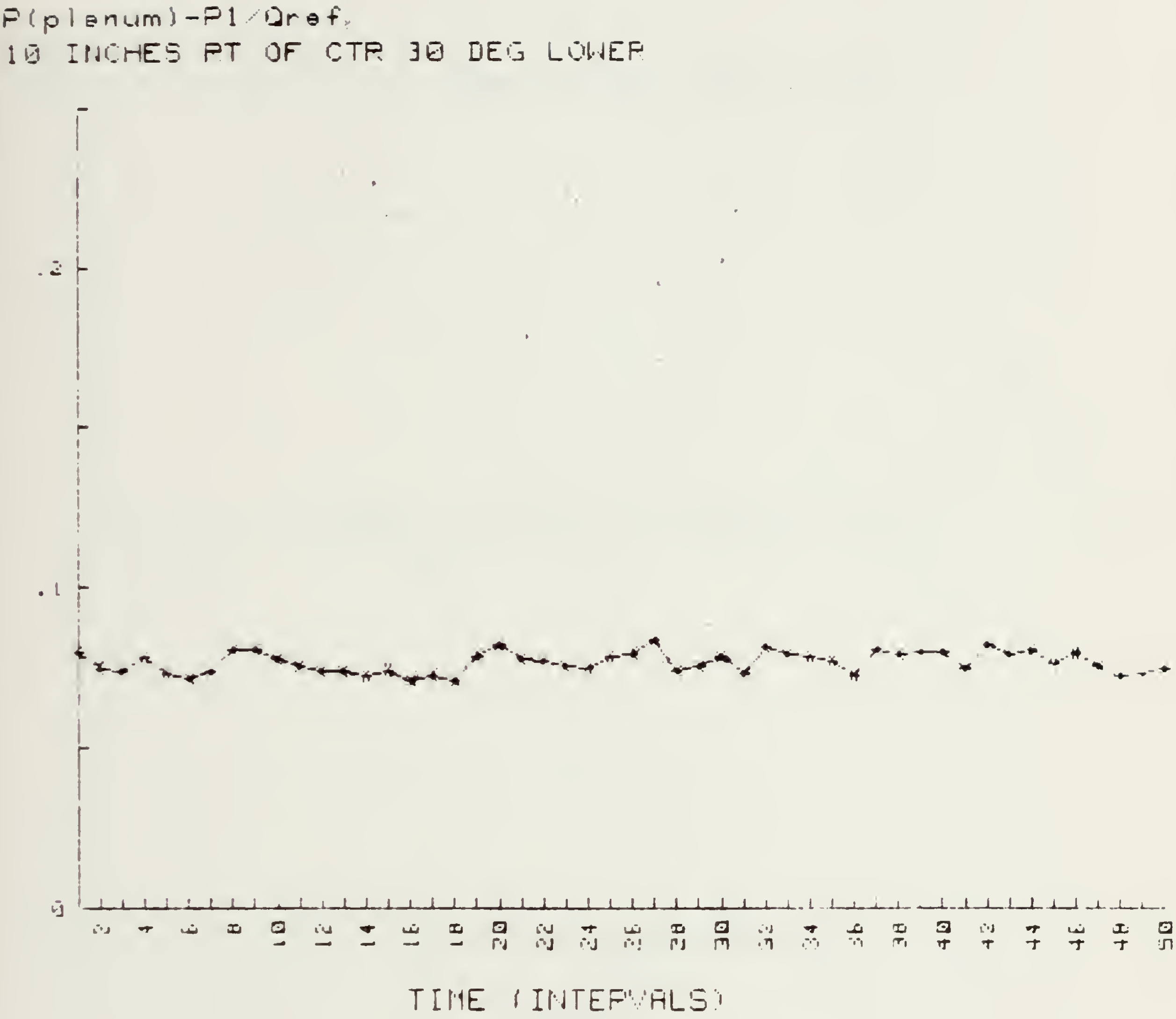


Fig. 33. Repetitive Samples with Fixed Probe Position (10" Right of CTR Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_t)/Q_{ref}$)

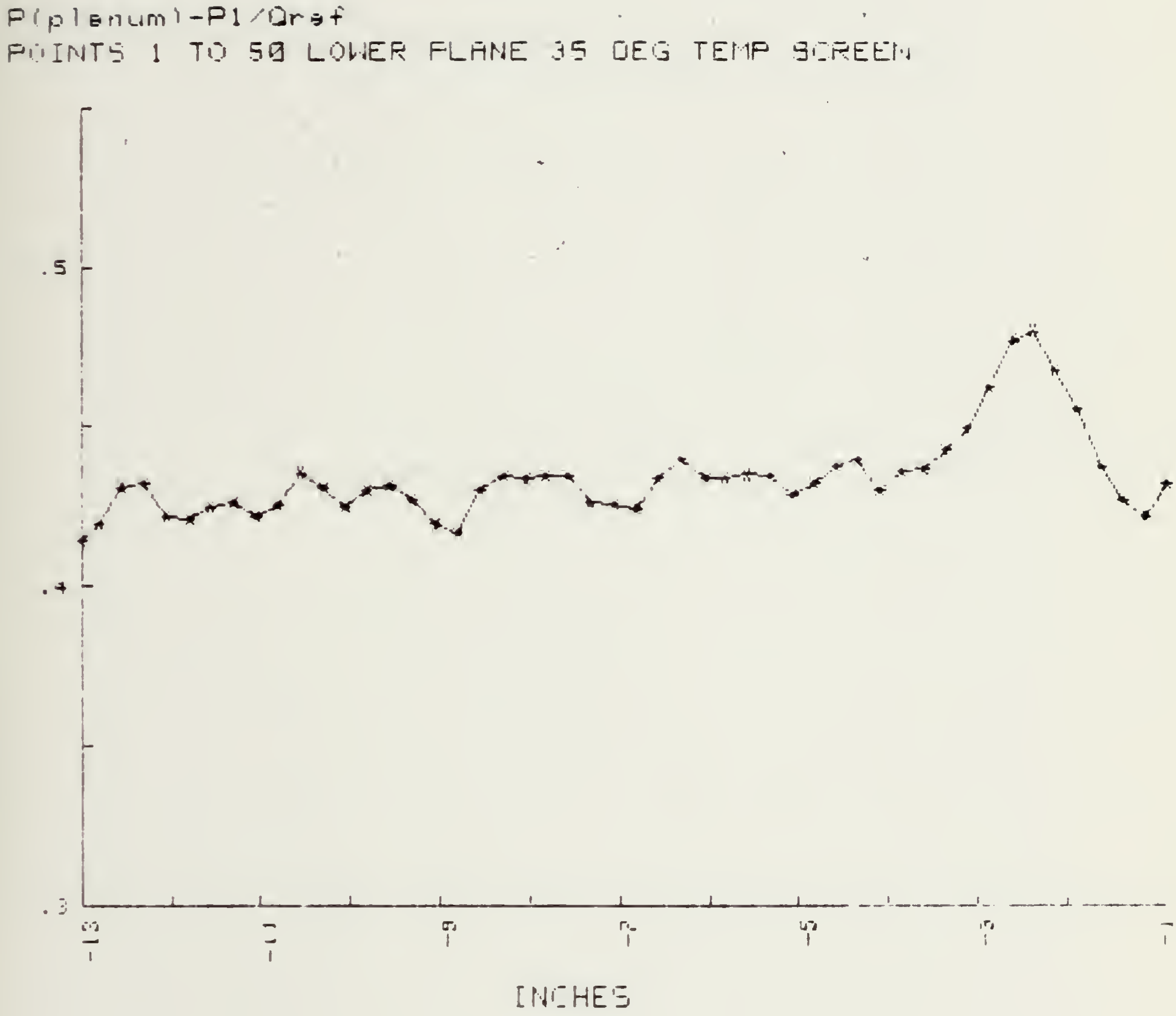


Fig. 34. Probe Survey Data at Midspan, Lower Plane 16 Mesh Screen, Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

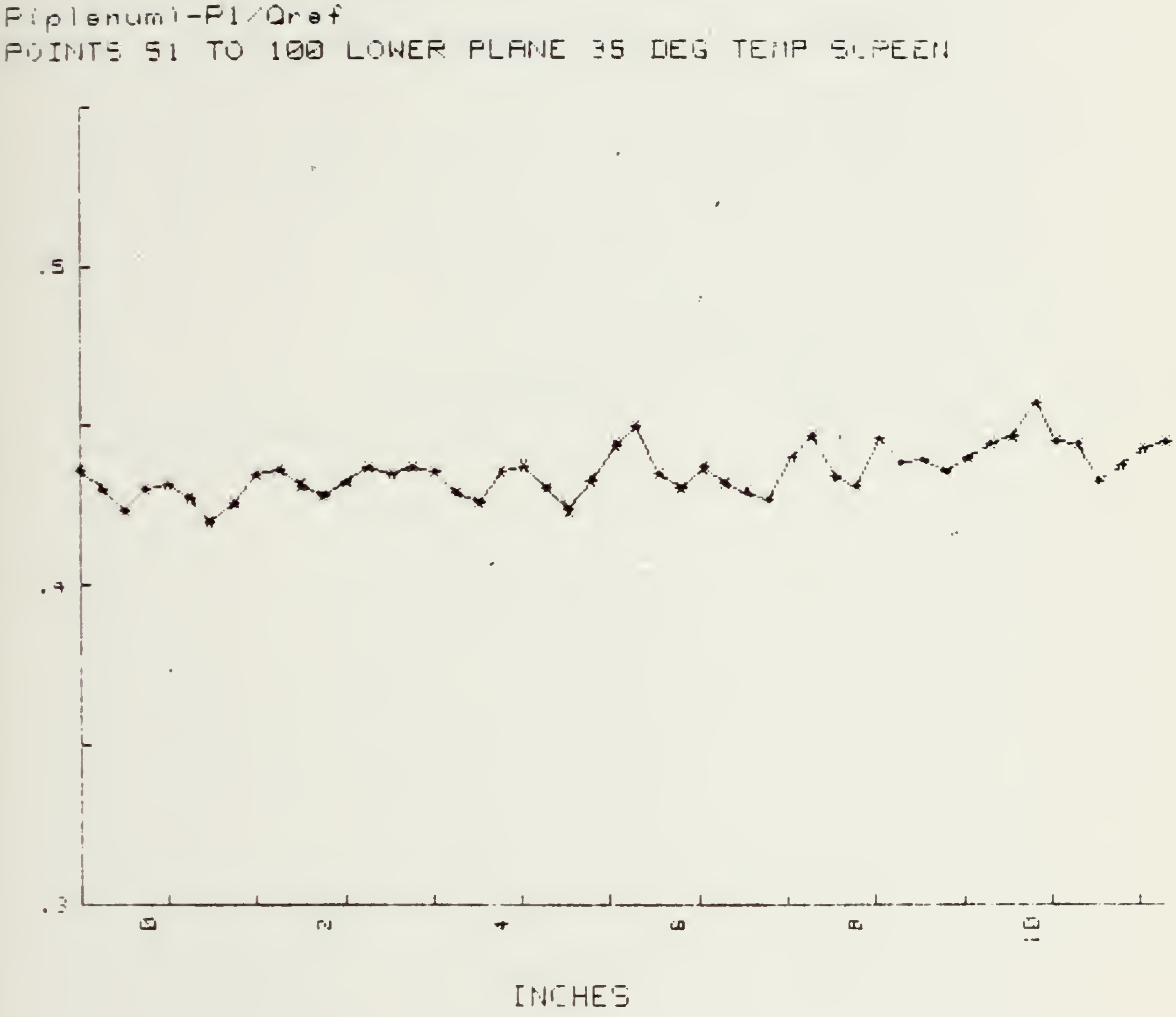


Fig. 35. Probe Survey Data at Midspan, Lower Plane
16 Mesh Screen, Walls at 35°, Points 51 to 100
$(P_{PLENUM} - P_t)/Q_{ref}$

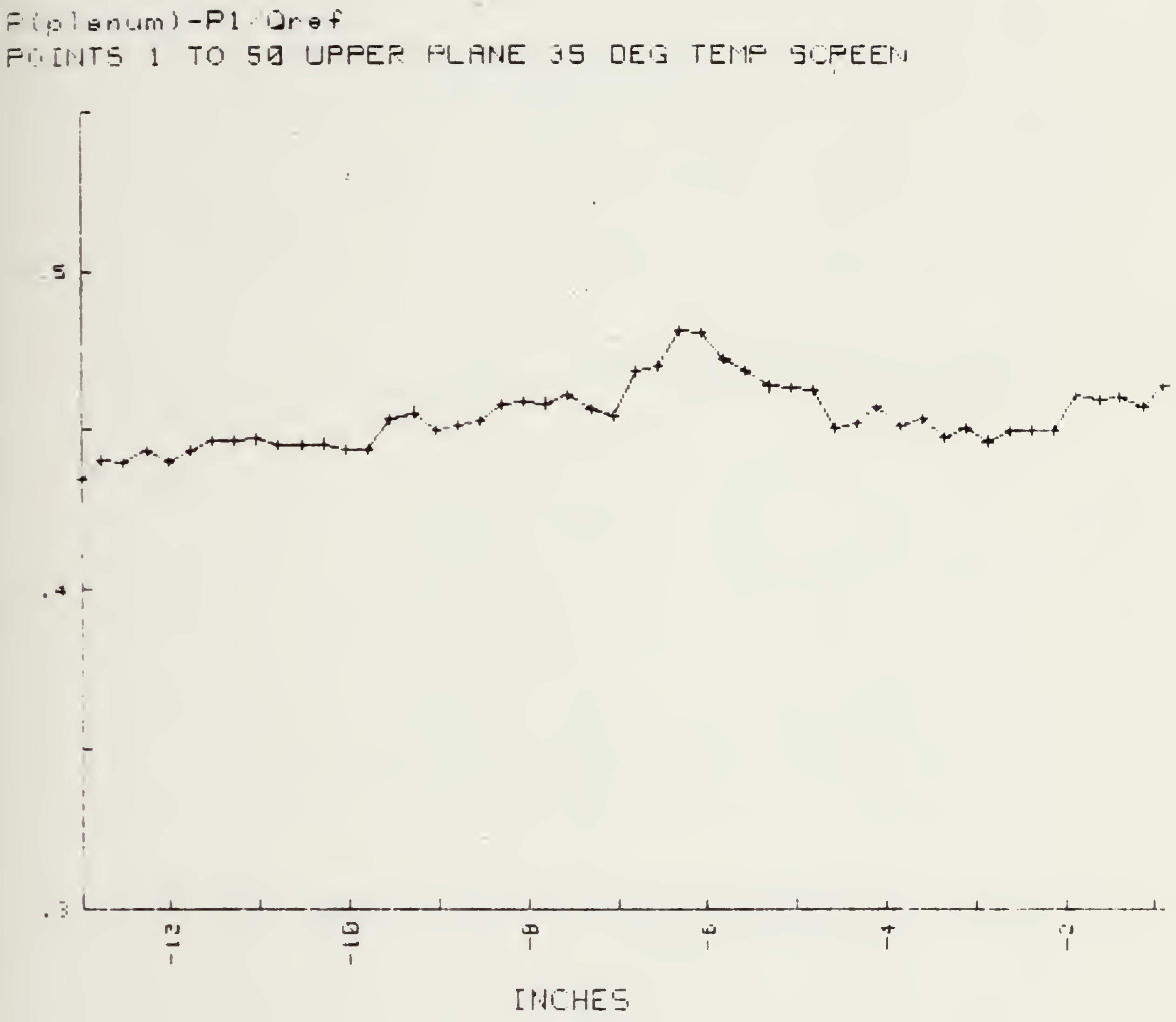


Fig. 36. Probe Survey Data at Midspan, Upper Plane
16 Mesh Screen, Walls at 35°, Points 1 to 50
$(P_{PLENUM} - P_t)/Q_{ref}$

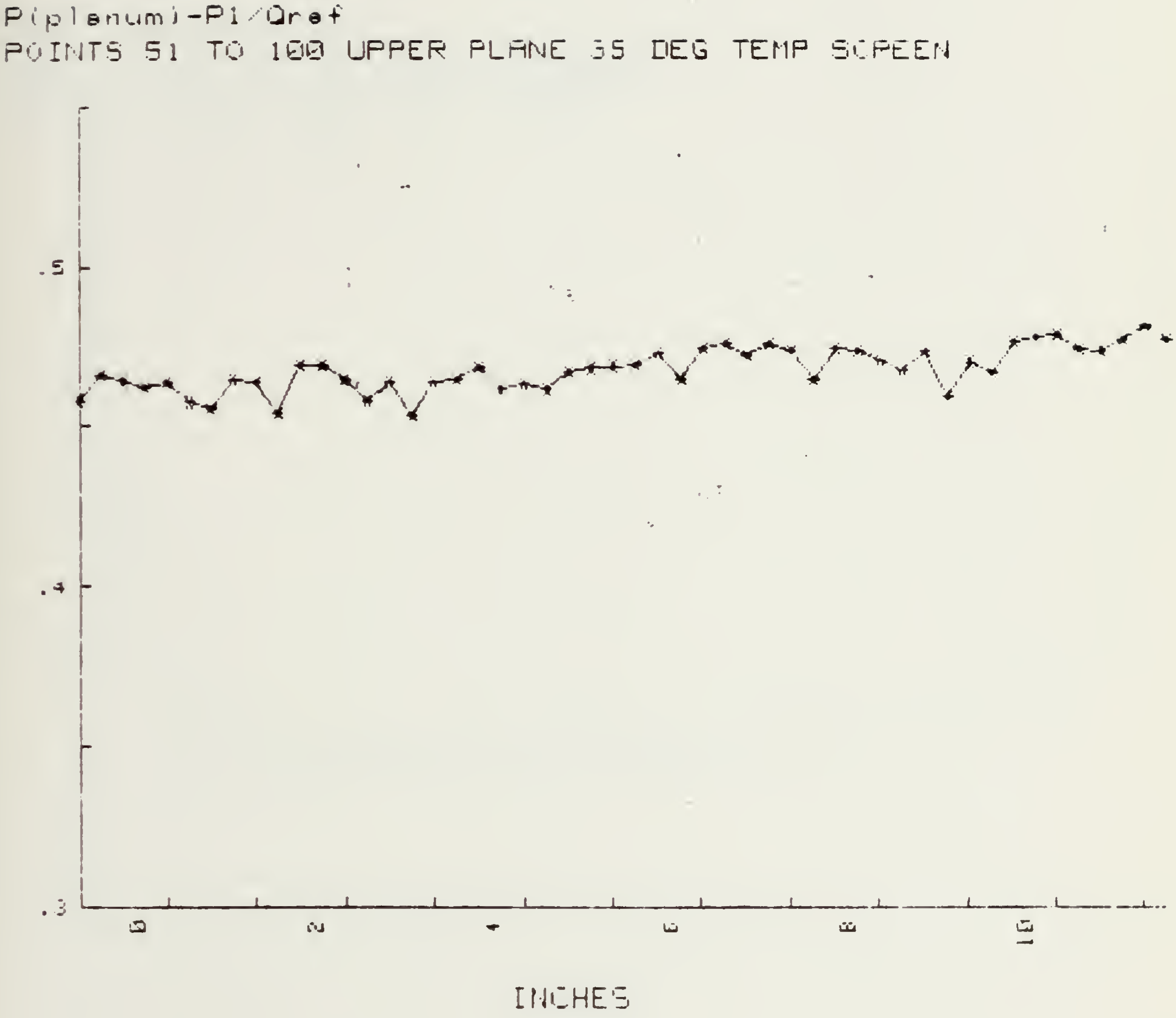


Fig. 37. Probe Survey Data at Midspan, Upper Plane 16 Mesh Screen, Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

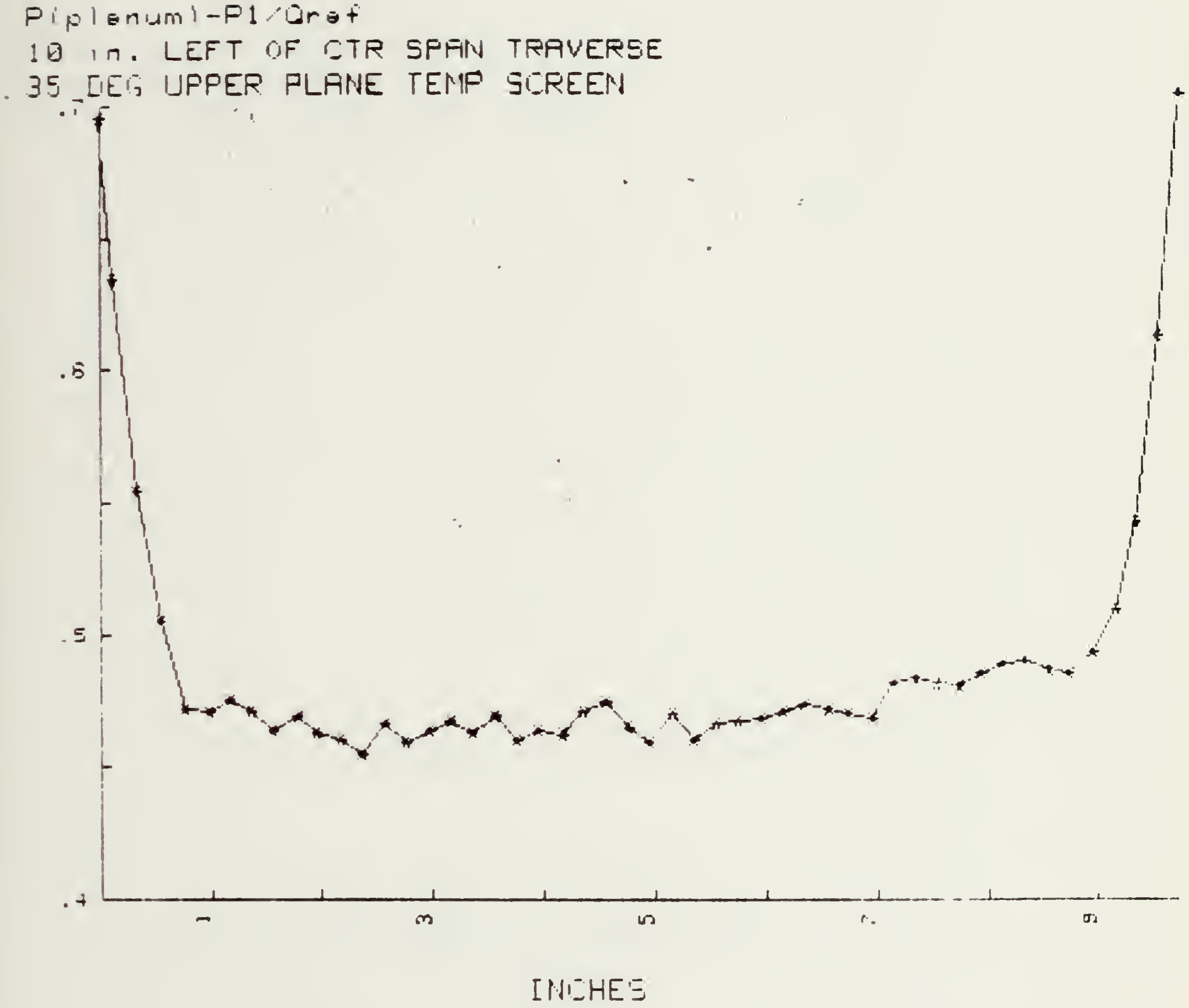


Fig. 38. Probe Survey Data Span Traverse, Lower Plane 16 Mesh Screen, Walls at 35°, 10" Left of CTR $(P_{PLENUM} - P_t)/Q_{ref}$

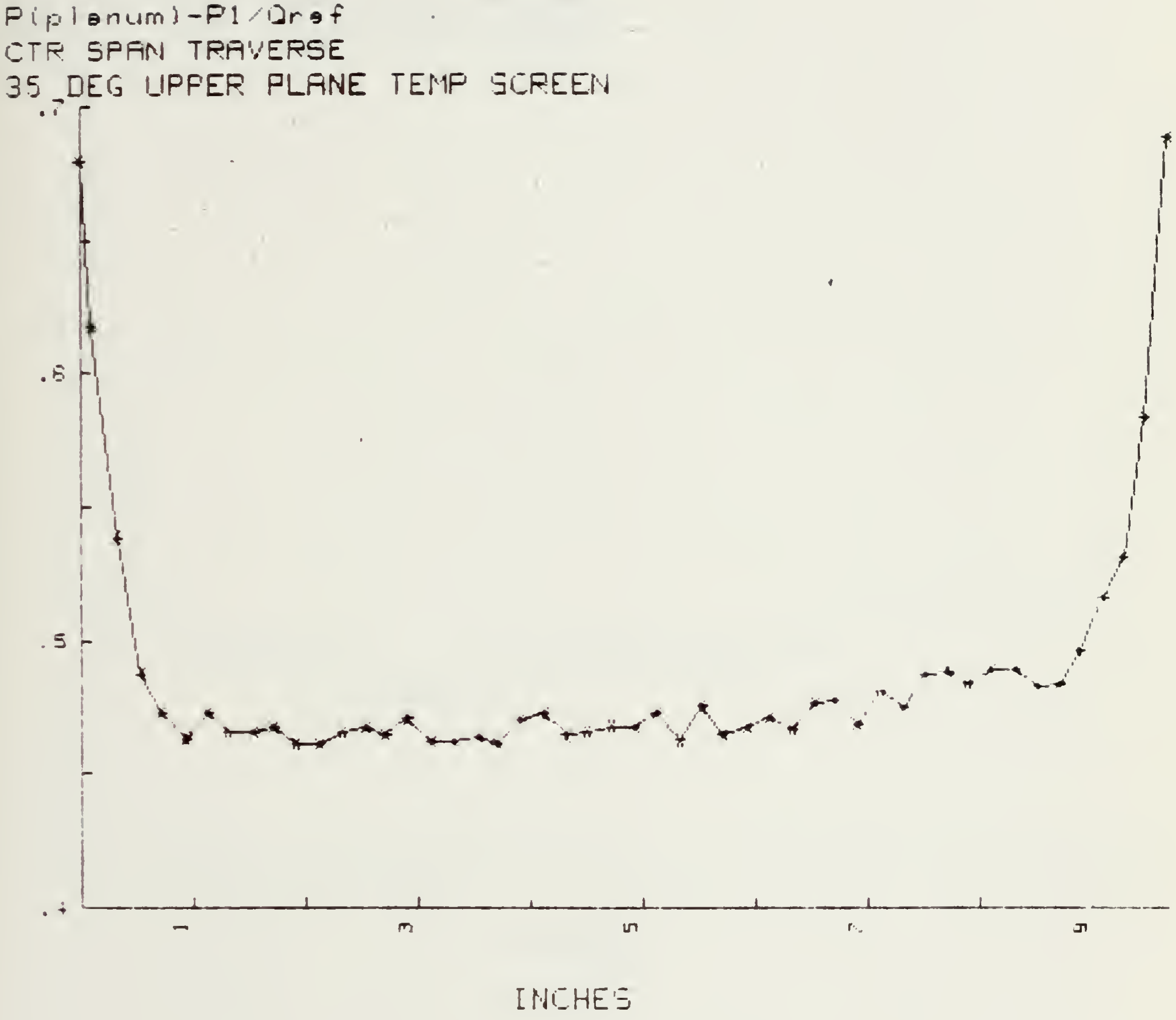


Fig. 39. Probe Survey Data Span Traverse, Lower Plane 16 Mesh Screen, Walls at 35°, Center of Test Section $(P_{PLENUM} - P_t)/Q_{ref}$

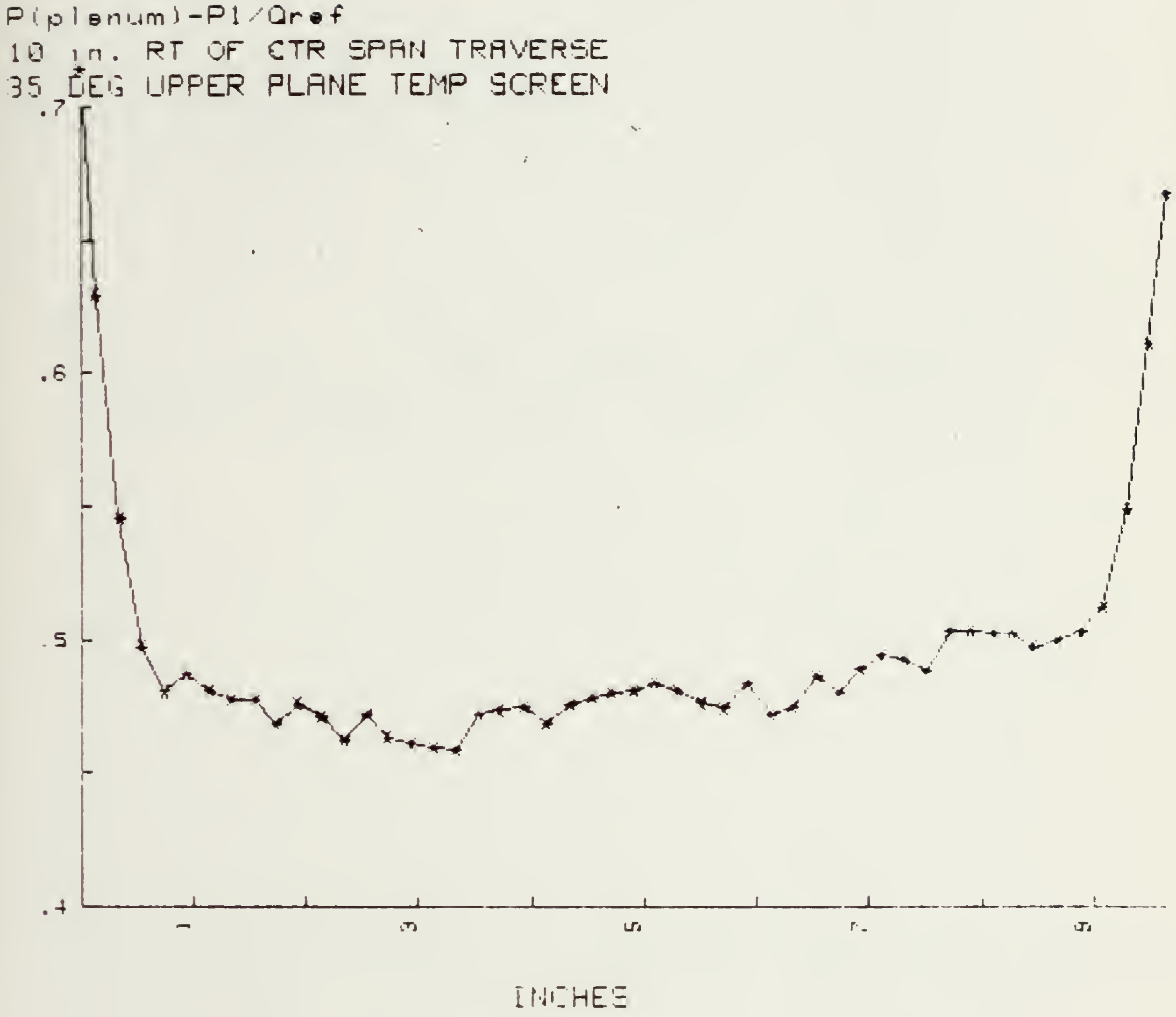


Fig. 40. Probe Survey Data Span Traverse, Lower Plane 16 Mesh Screen, Walls at 35°, Center of Test Section $(P_{PLENUM} - P_t)/Q_{ref}$

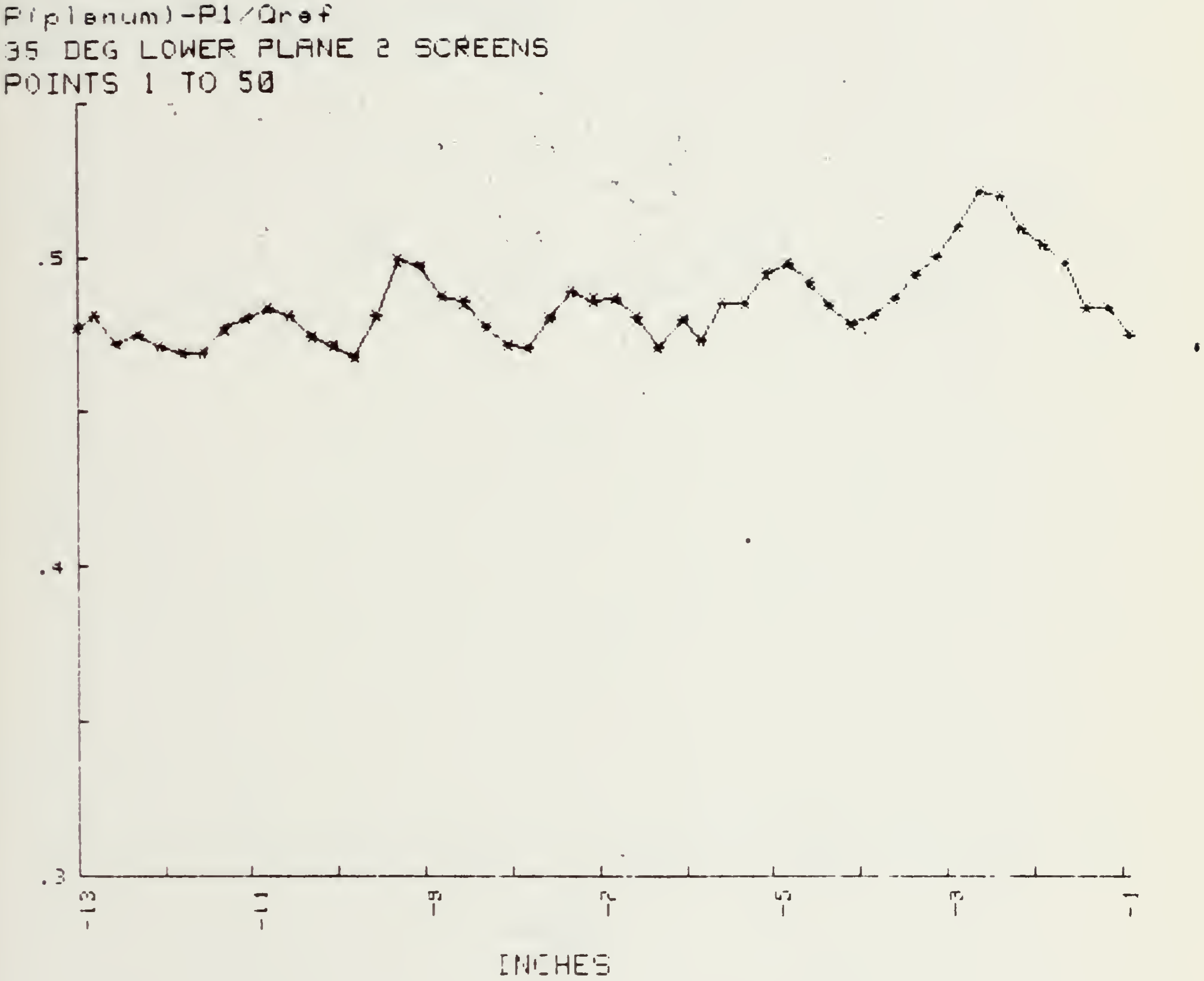


Fig. 41. Probe Survey Data at Midspan, Lower Plane 16 Mesh and 2 Mesh, Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

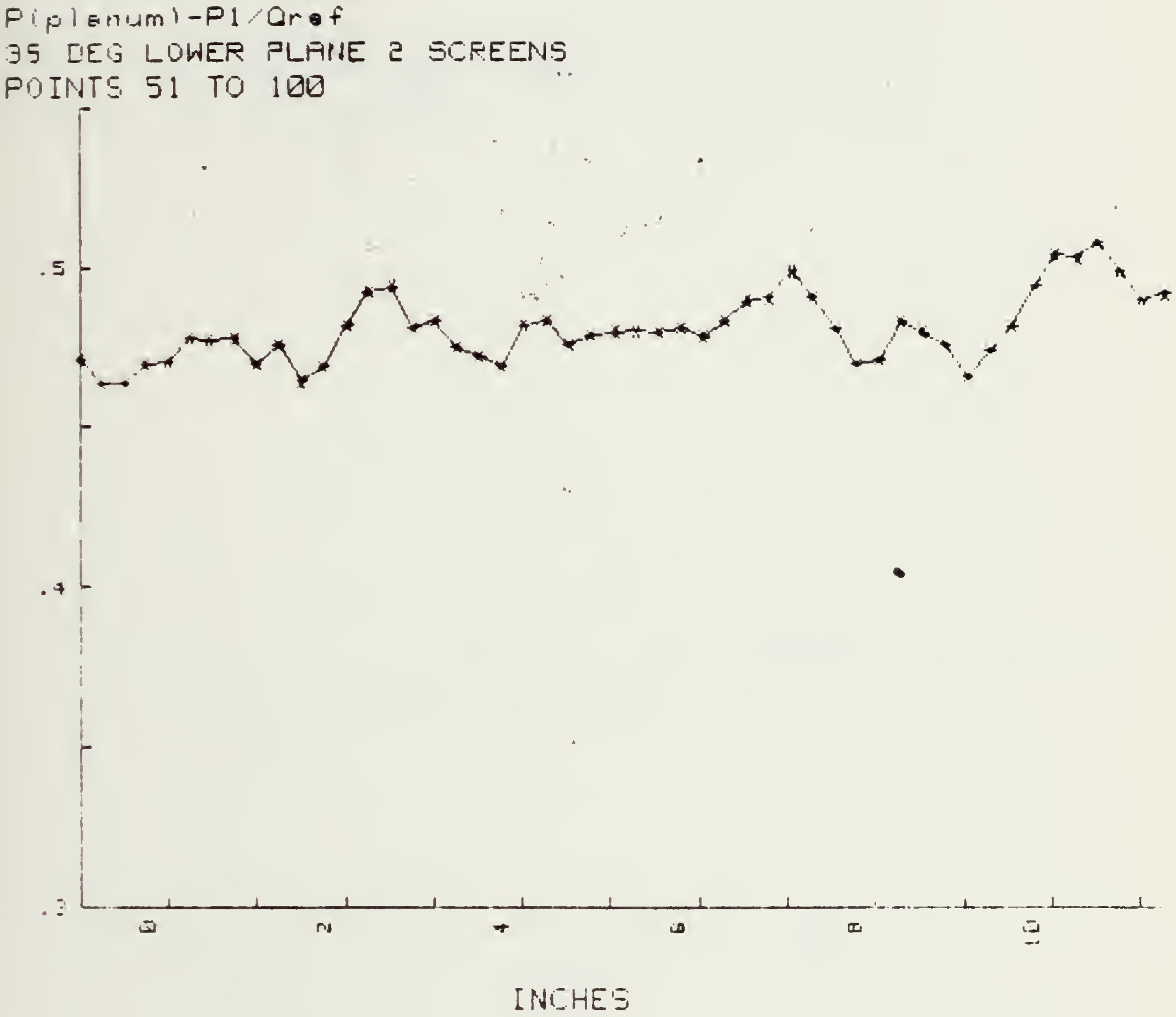


Fig. 42. Probe Survey Data at Midspan, Lower Plane 16 Mesh and 2 Mesh, Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

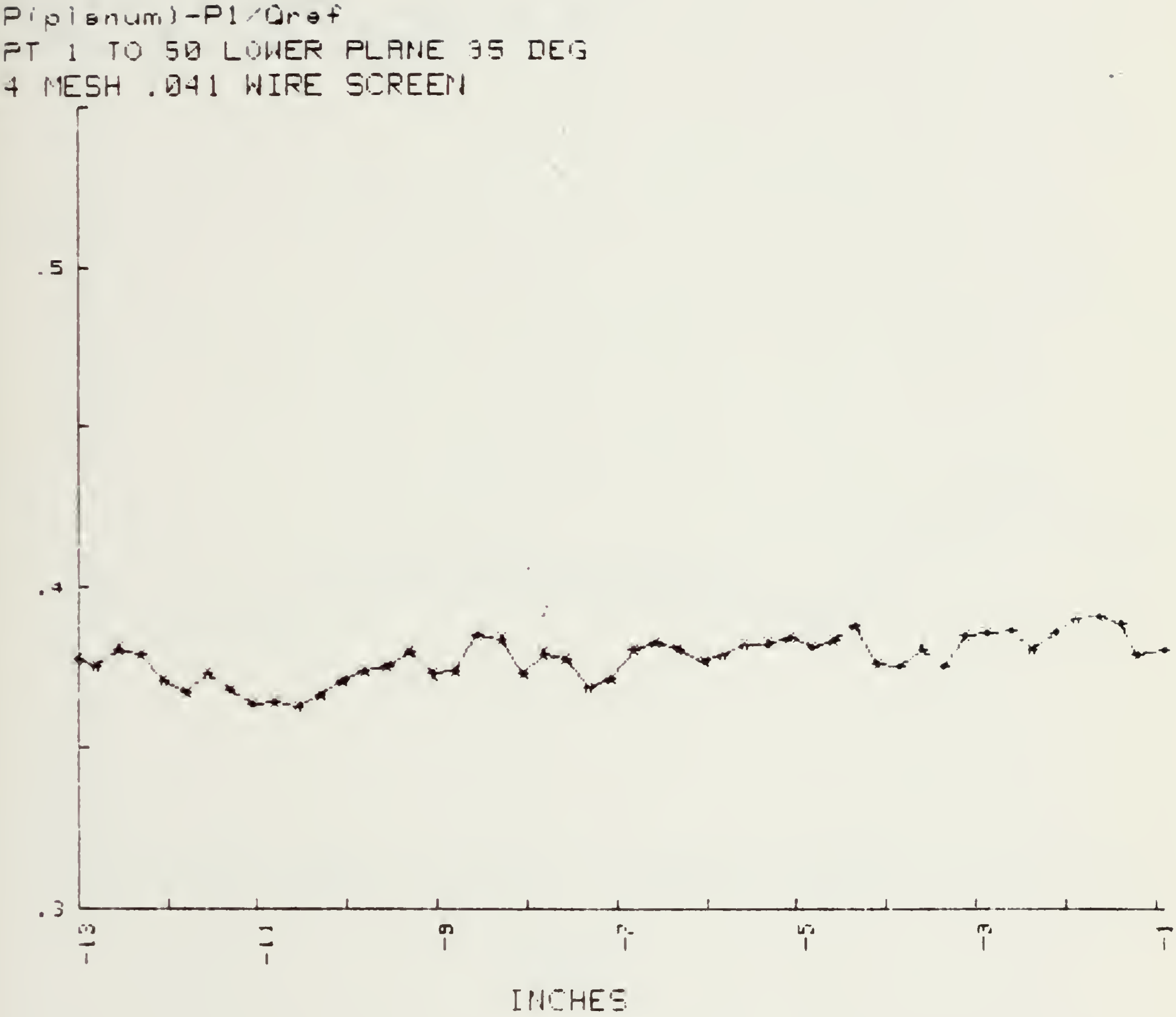


Fig. 43. Probe Survey Data at Midspan, Lower Plane 4 Mesh Screen, Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

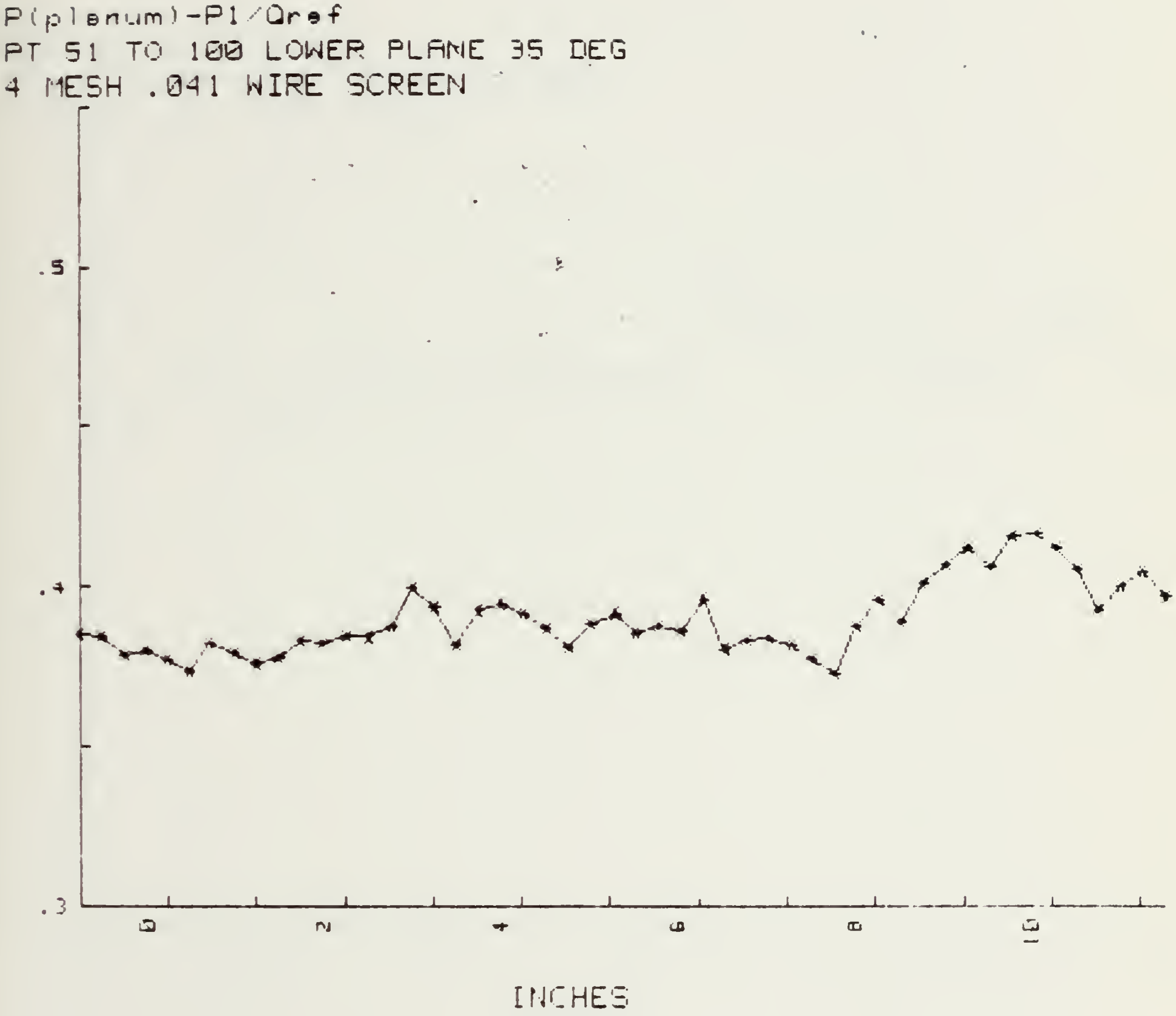


Fig. 44. Probe Survey Data at Midspan, Lower Plane 4 Mesh Screen, Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

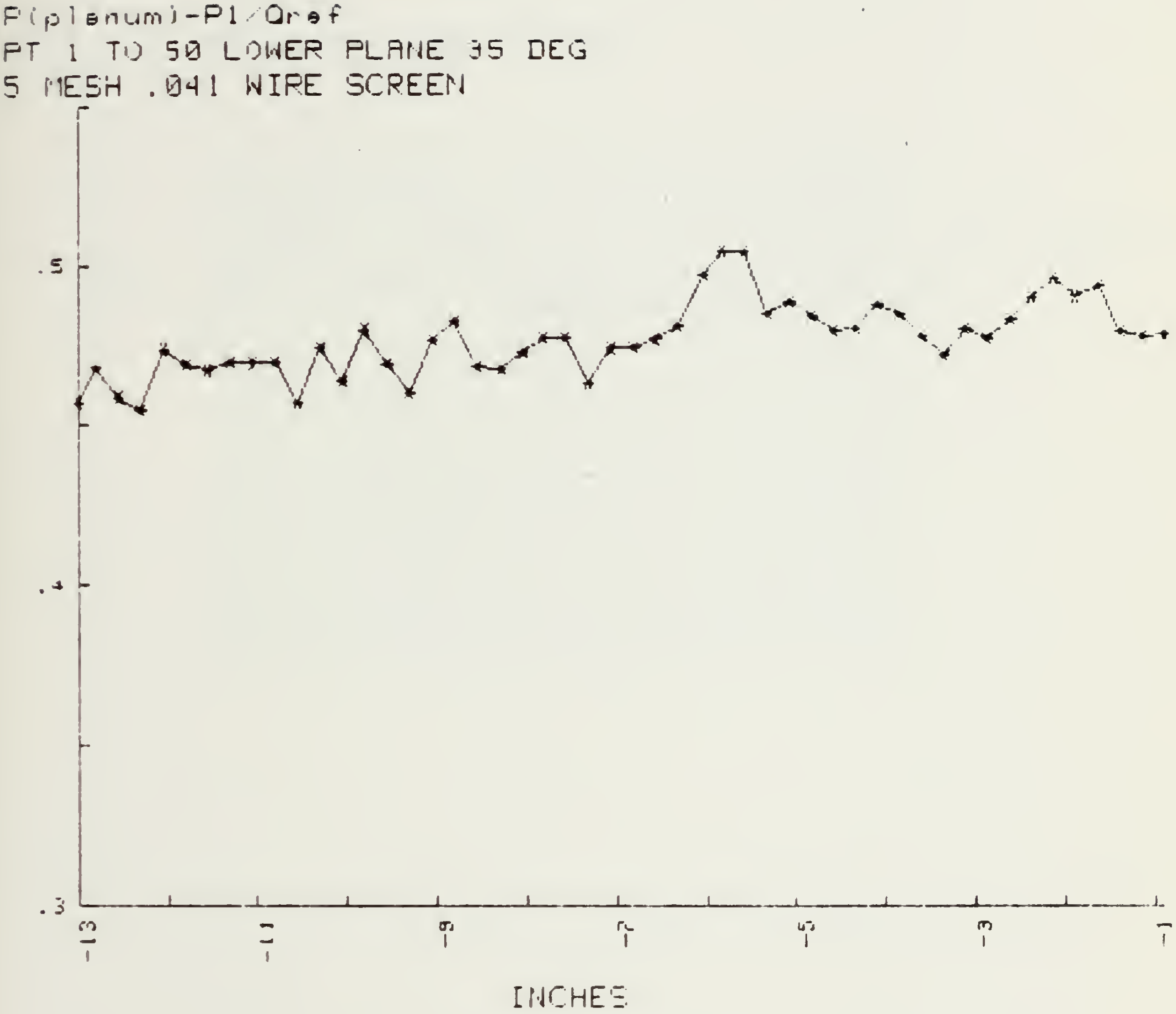


Fig. 45. Probe Survey Data at Midspan, Lower Plane 5 Mesh Screen, Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

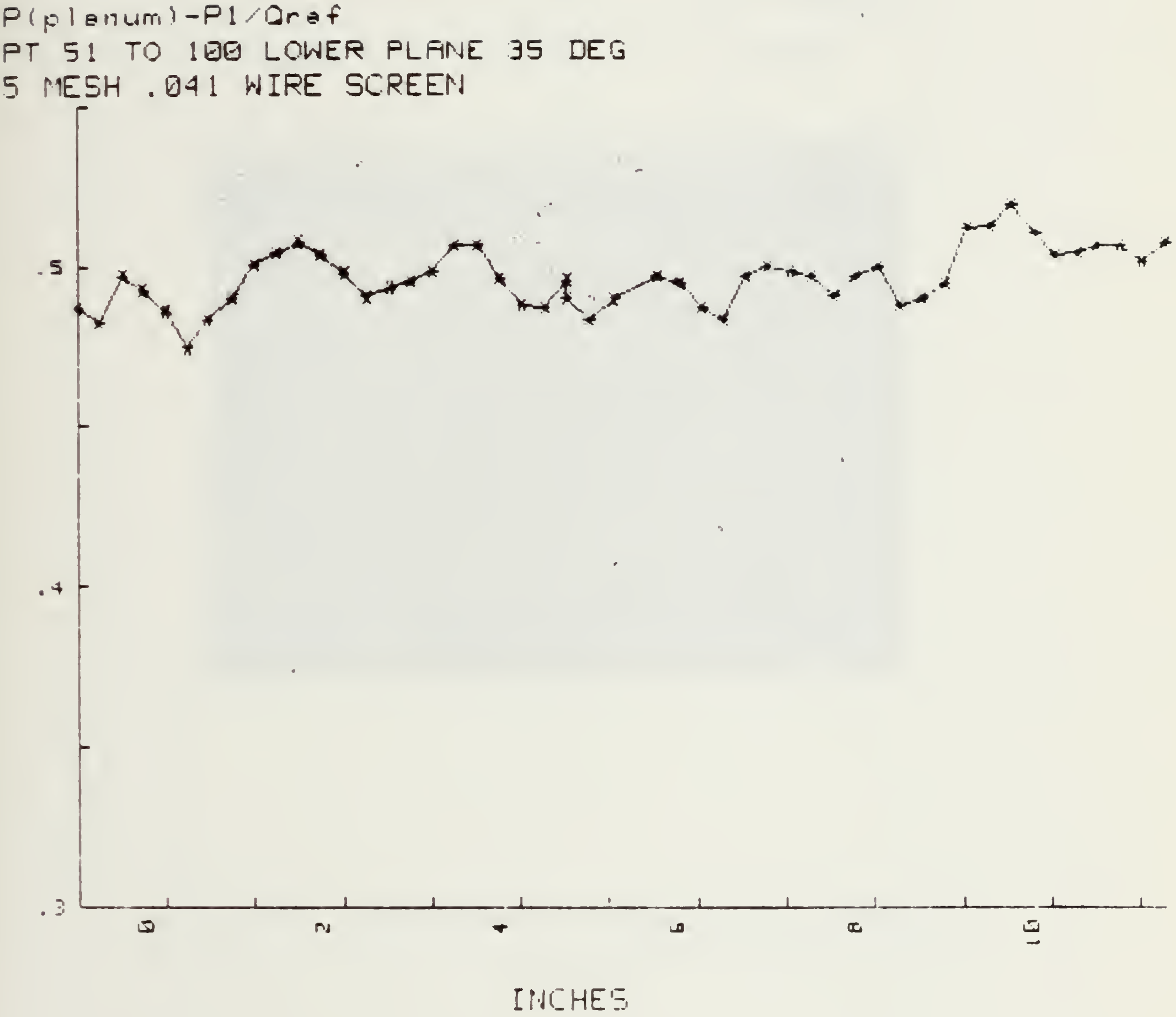


Fig. 46. Probe Survey Data at Midspan, Lower Plane 5 Mesh Screen, Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

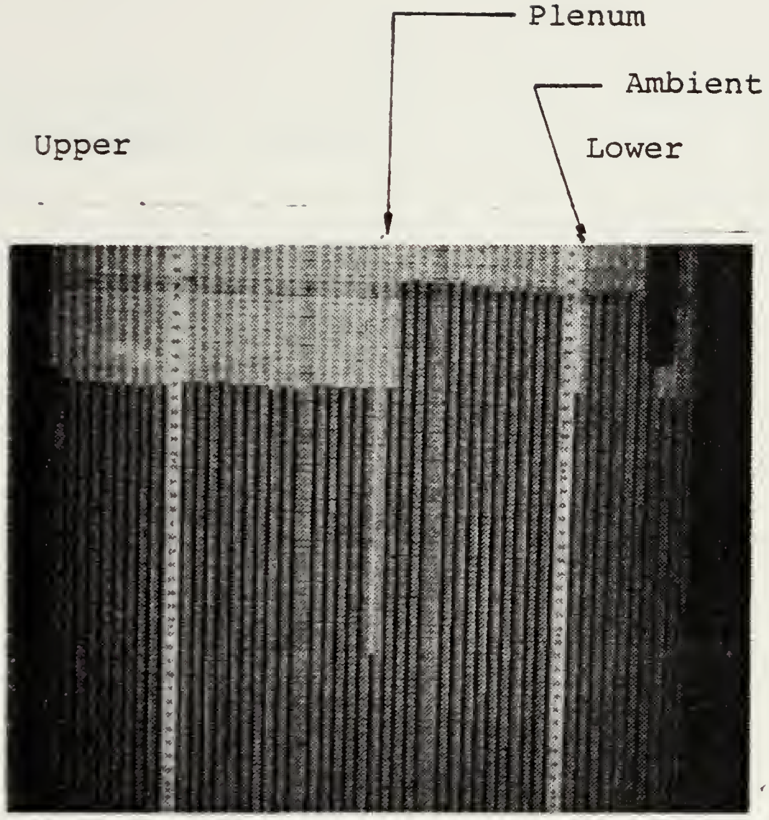


Fig. 47. Wall Static Pressure Distribution

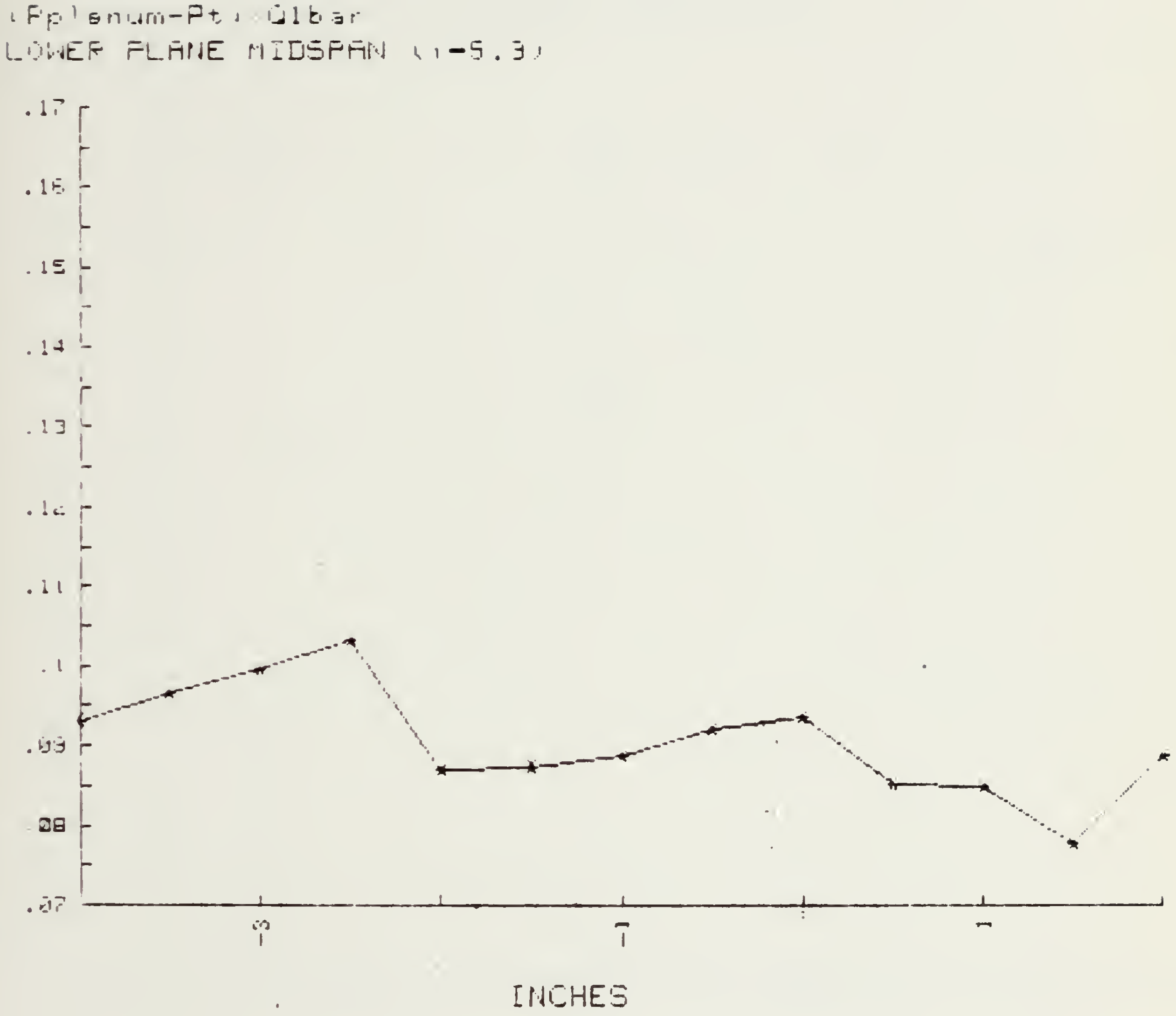
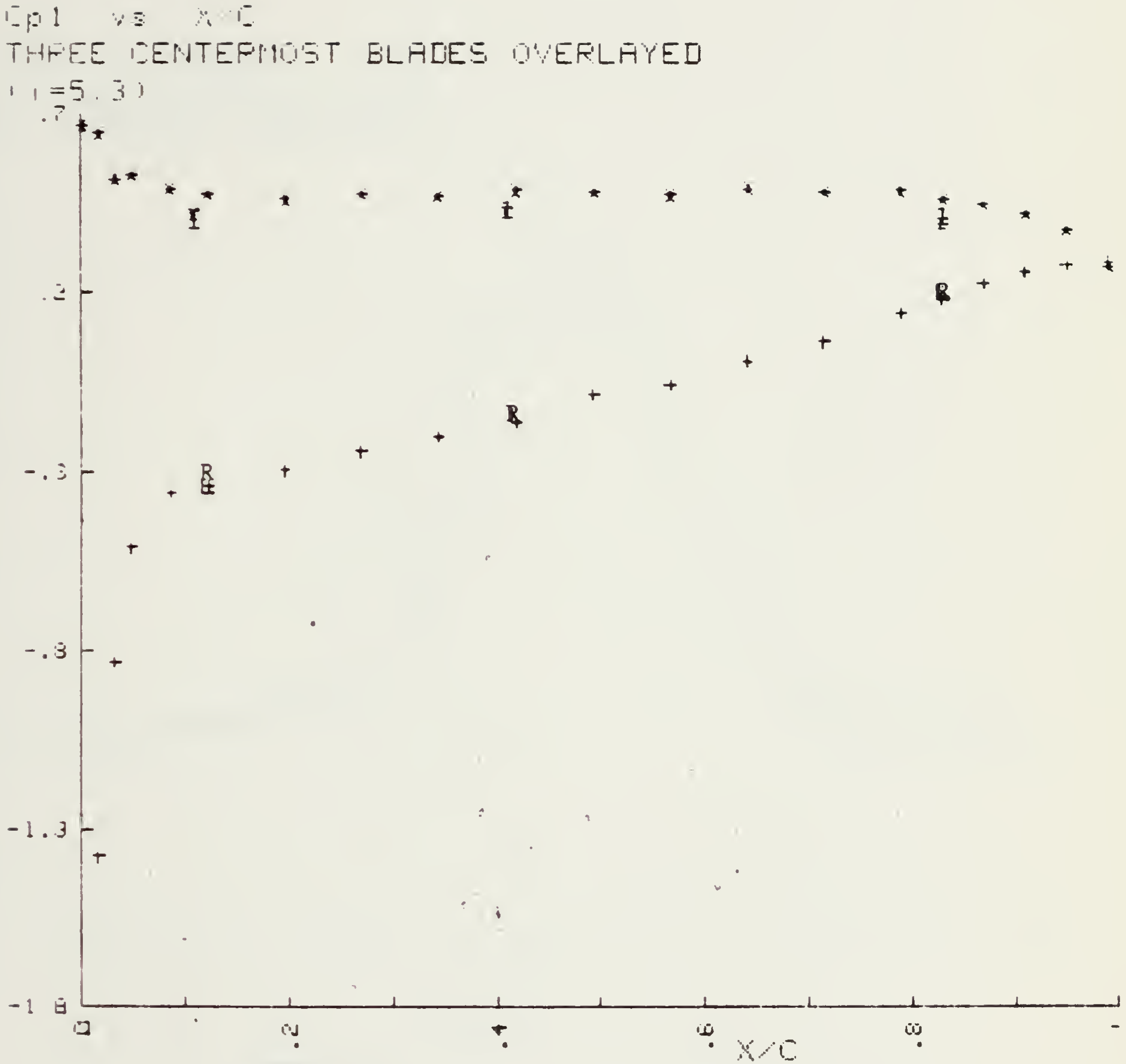


Fig. 48. Probe Survey Data at Upstream Midspan (i = 5.3, $(P_{PLENUM} - P_t)/\overline{Q}_1$, Lower Plane)



Symbols:

BLADE	LEFT	CENTER	RIGHT
Pressure Side	l	*	r
Suction Side	L	+	R

Fig. 49. Blade Surface Pressure Distribution on Three Centermost Blades (i = 5.3)

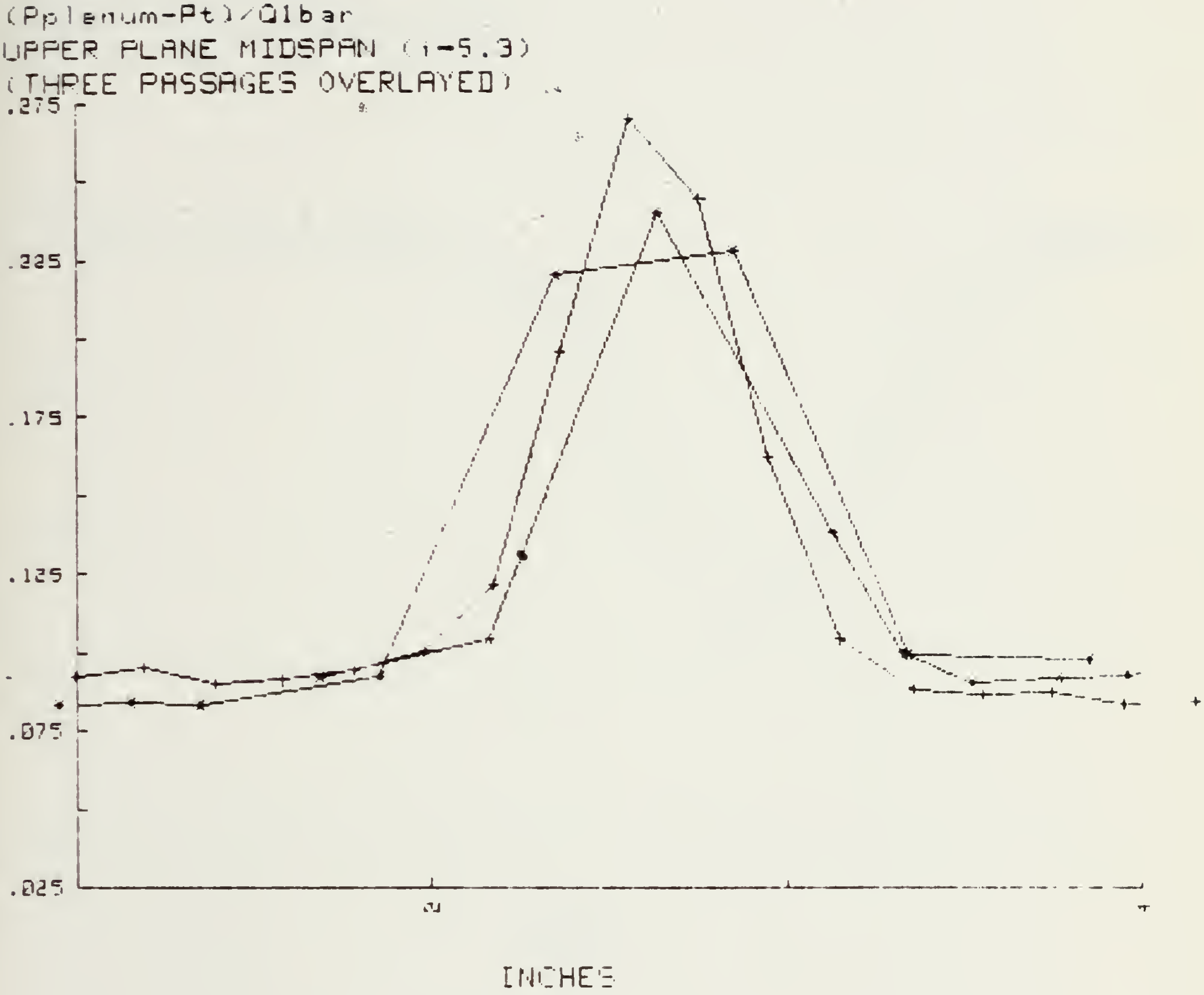


Fig. 50. Probe Survey Data at Midspan
(i = 5.3, $(P_{PLENUM} - P_t)/\bar{Q}_1$, Upper Plane)

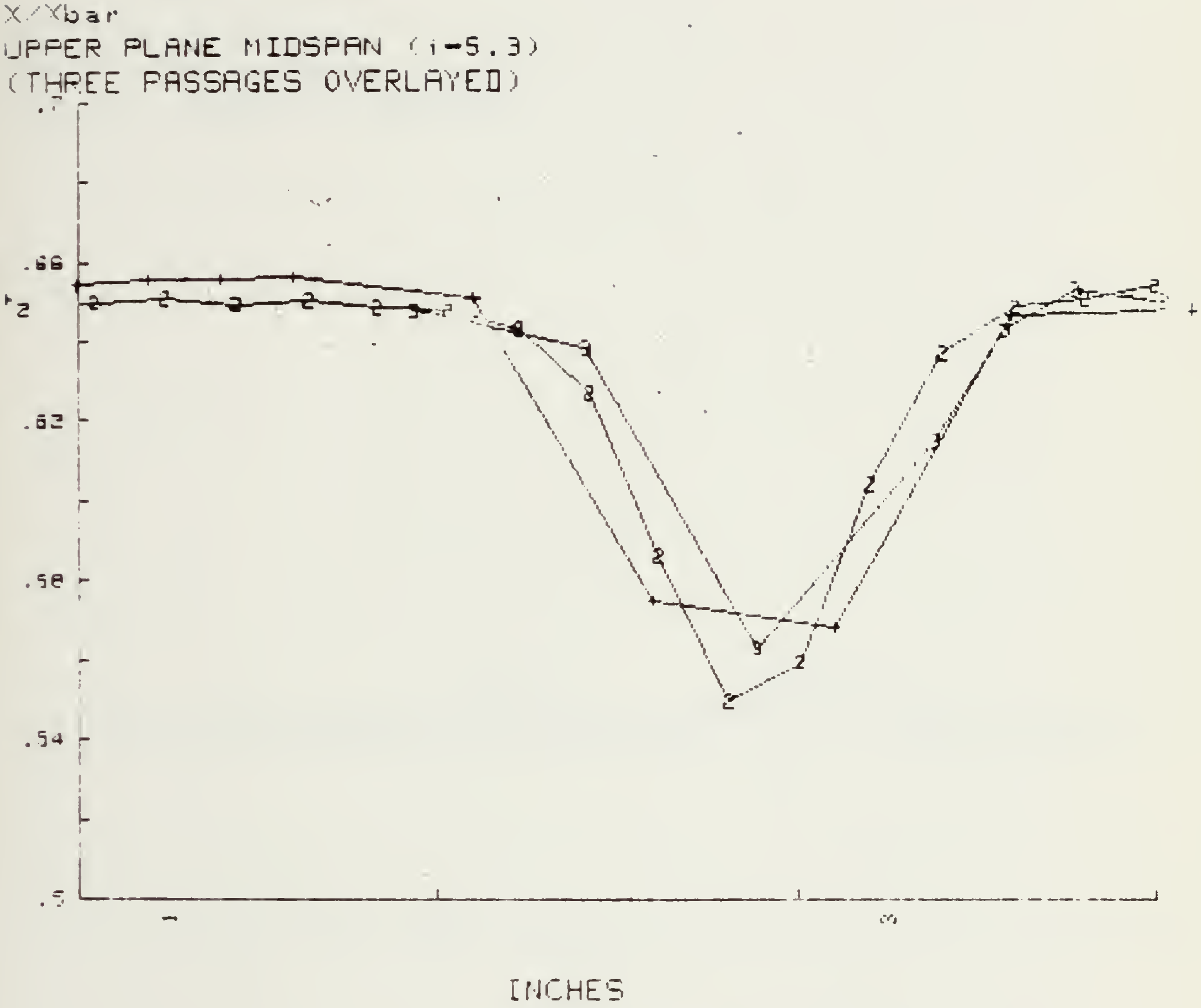


Fig. 51. Probe Survey Data at Midspan
(i = 5.3, $(X/\overline{X})$, Upper Plane)

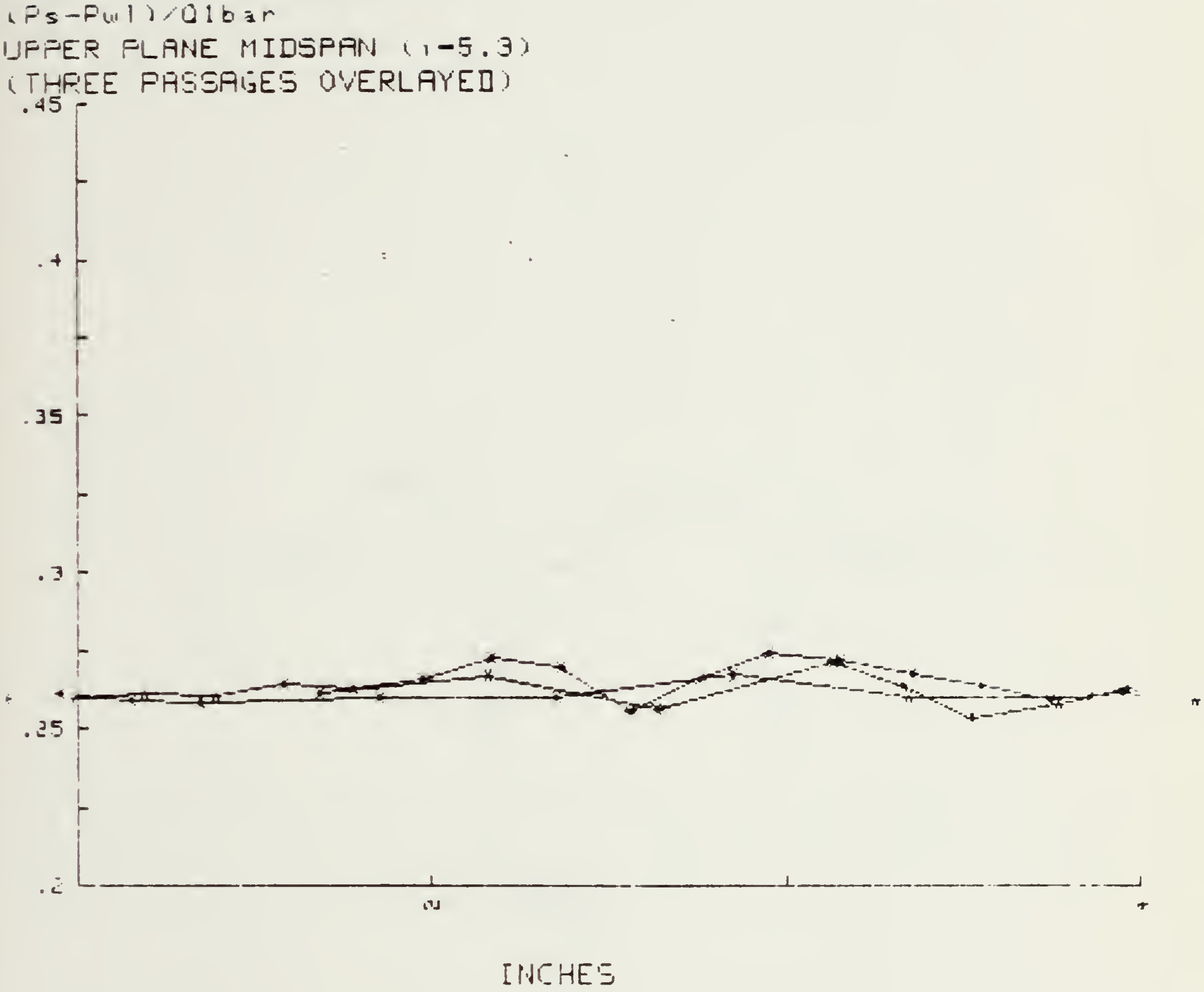


Fig. 52. Probe Survey Data at Midspan
(i = 5.3, $(P_s - P_{w1})/\bar{Q}_1$, Upper Plane)

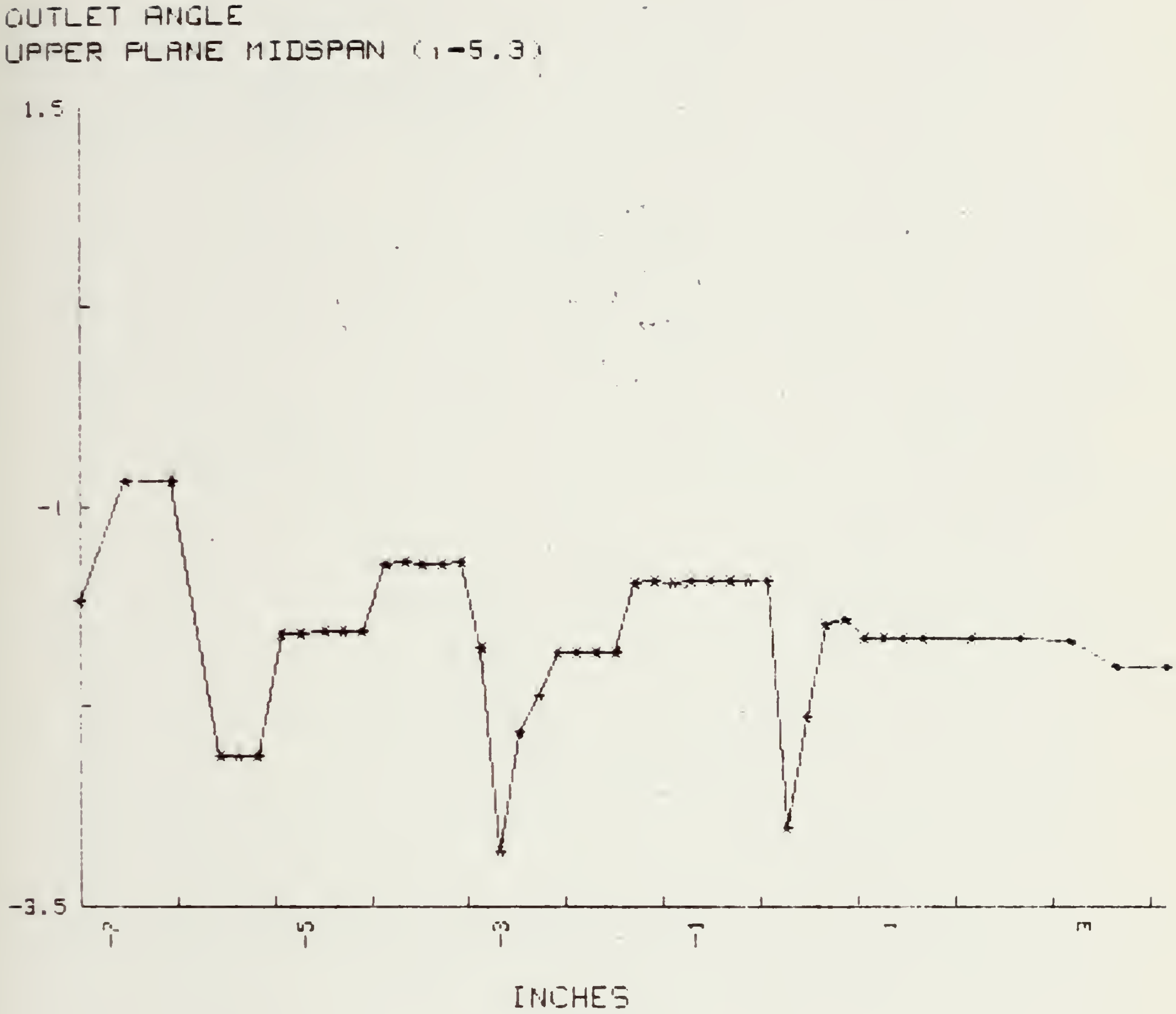


Fig. 53. Probe Survey Data at Midspan
(i = 5.3, Outlet Angle, Upper Plane)

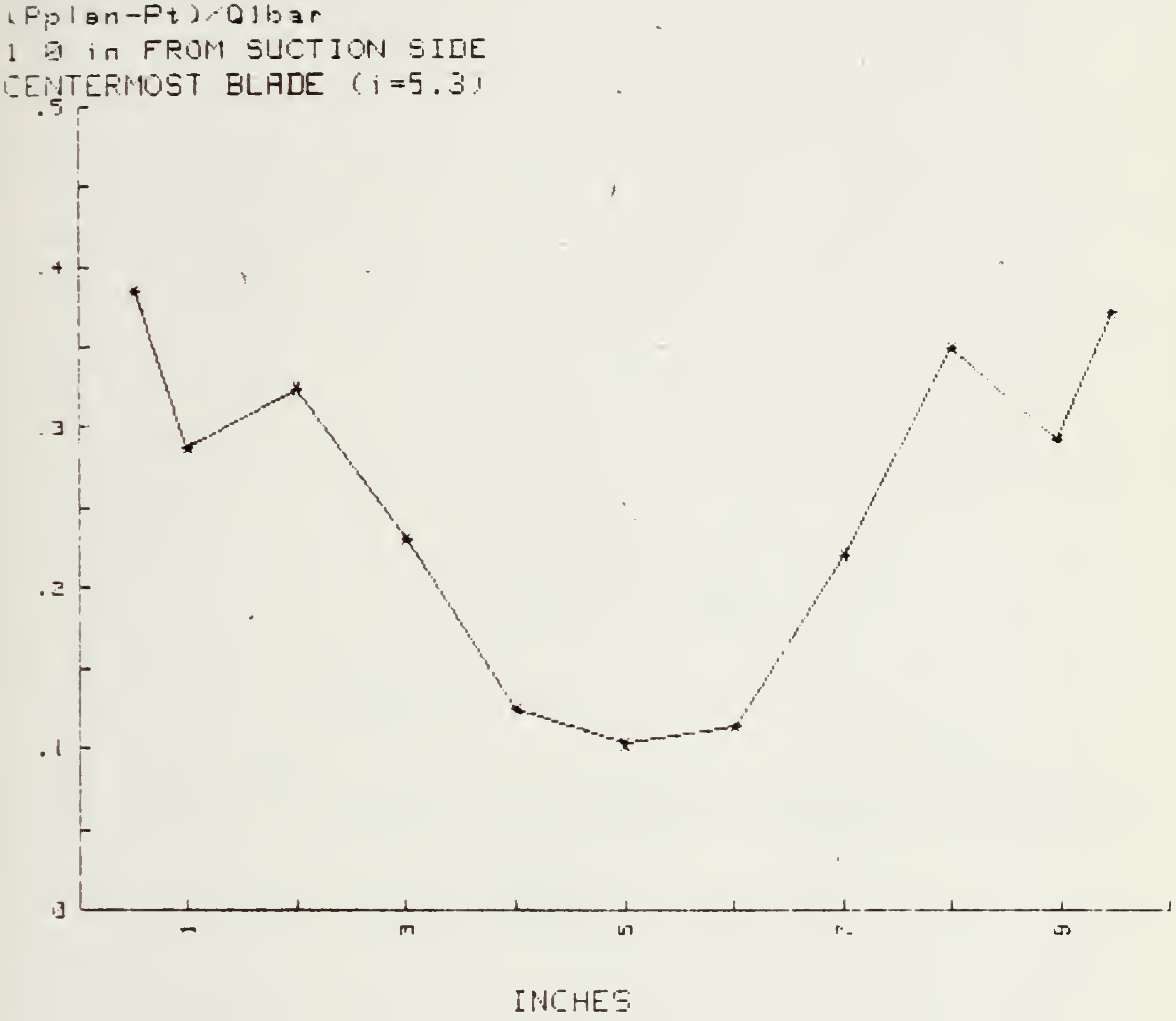


Fig. 54. Spanwise Probe Data Surveyed 1 in. from Suction Side of Centermost Blade (i = 5.3, $(P_{PLENUM} - P_t)/\bar{Q}_1$, Upper Plane)

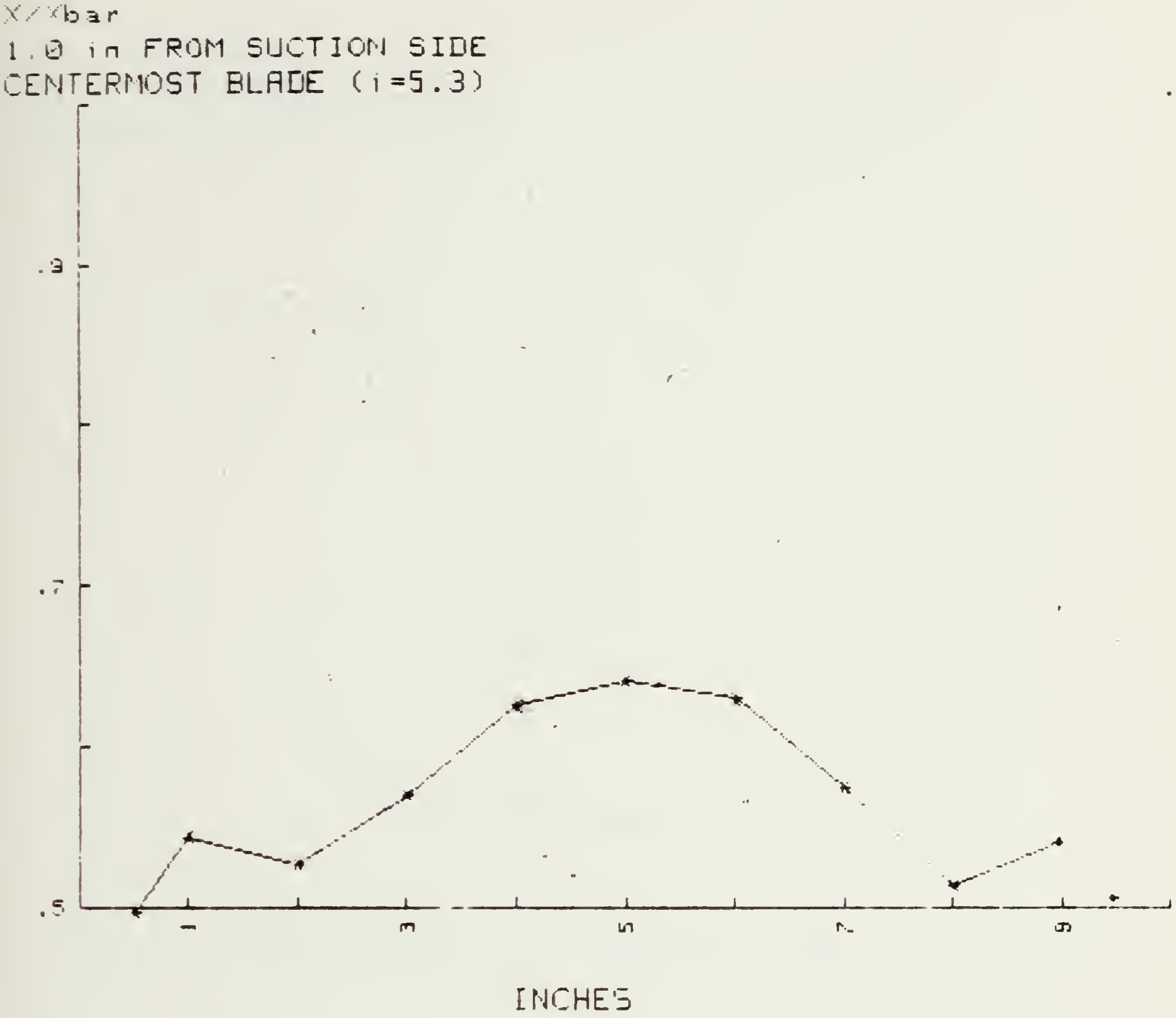


Fig. 55. Spanwise Probe Data Surveyed 1 in. from Suction Side of Centermost Blade (i = 5.3, $X/\overline{X}$, Upper Plane)

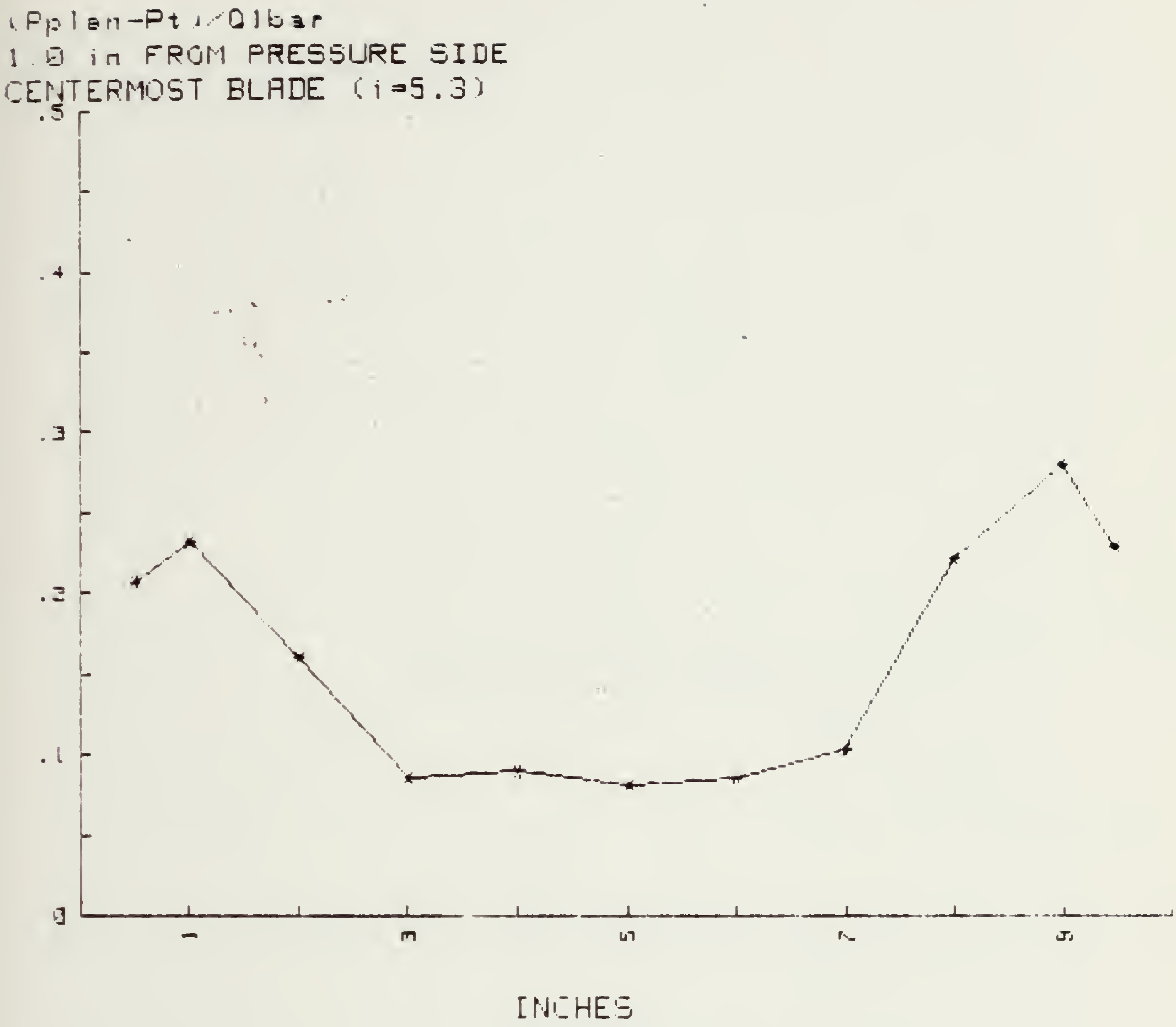


Fig. 56. Spanwise Probe Data Surveyed 1 in. from Pressure Side of Centermost Blade (i = 5.3, $(P_{PLENUM} - P_t)/\overline{Q}_1$, Upper Plane)

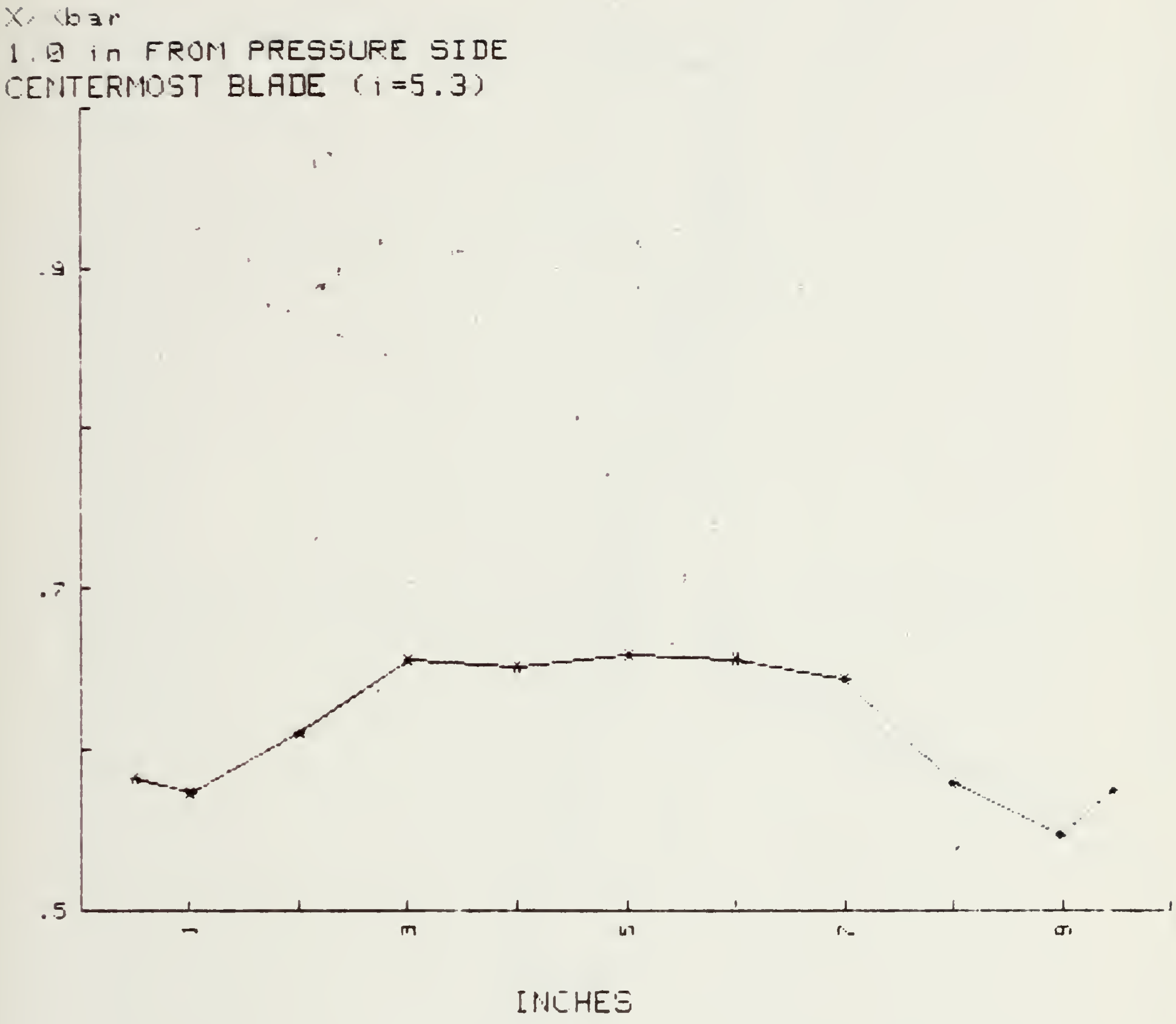


Fig. 57. Spanwise Probe Data Surveyed 1 in. from Pressure Side of Centermost Blade ($i = 5.3$, $X/\overline{X}$, Upper Plane)

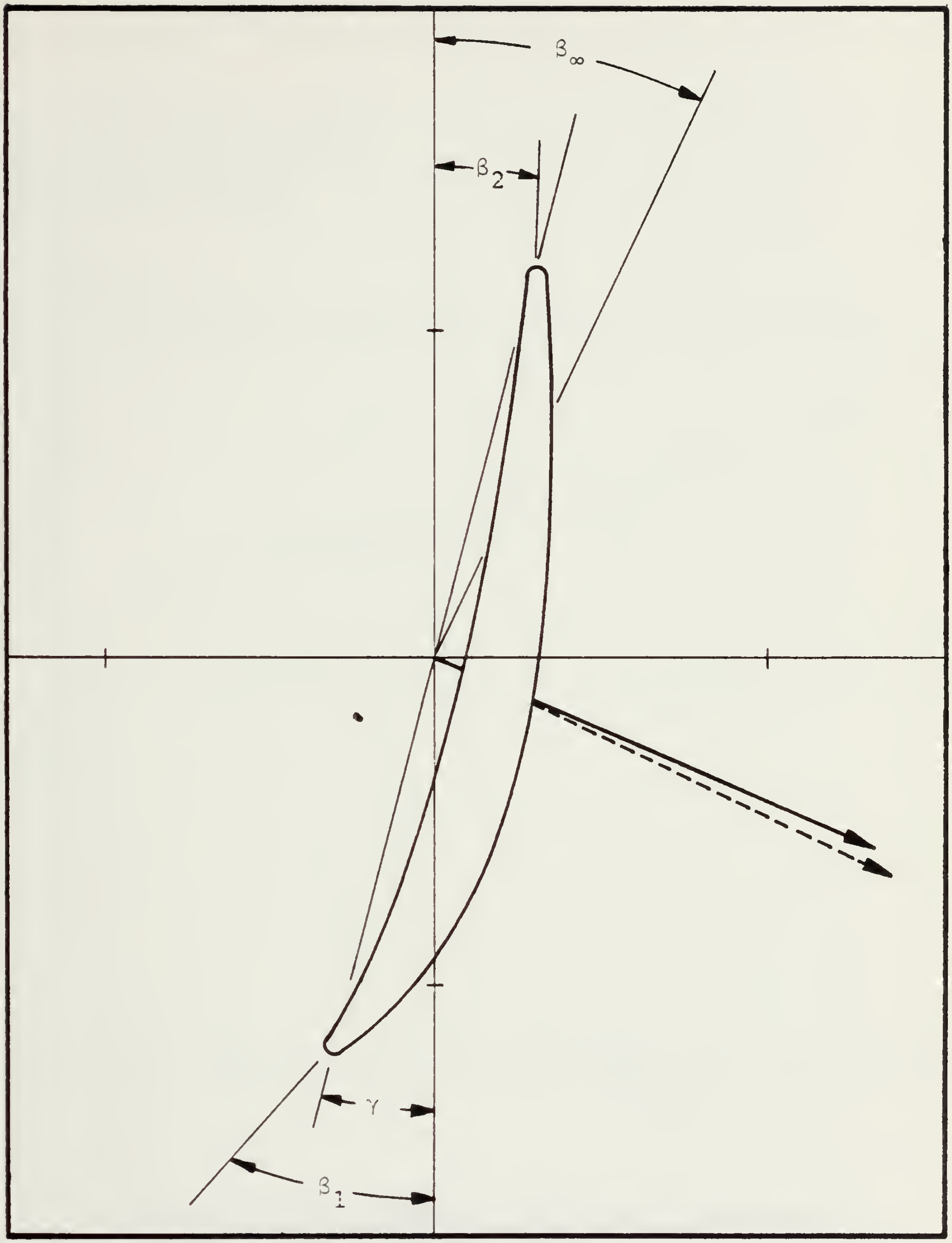


Fig. 58. Resultant Blade Force Vectors by Momentum Balance (– – – – –) and from Surface Pressure Integration (————) i = 5.3

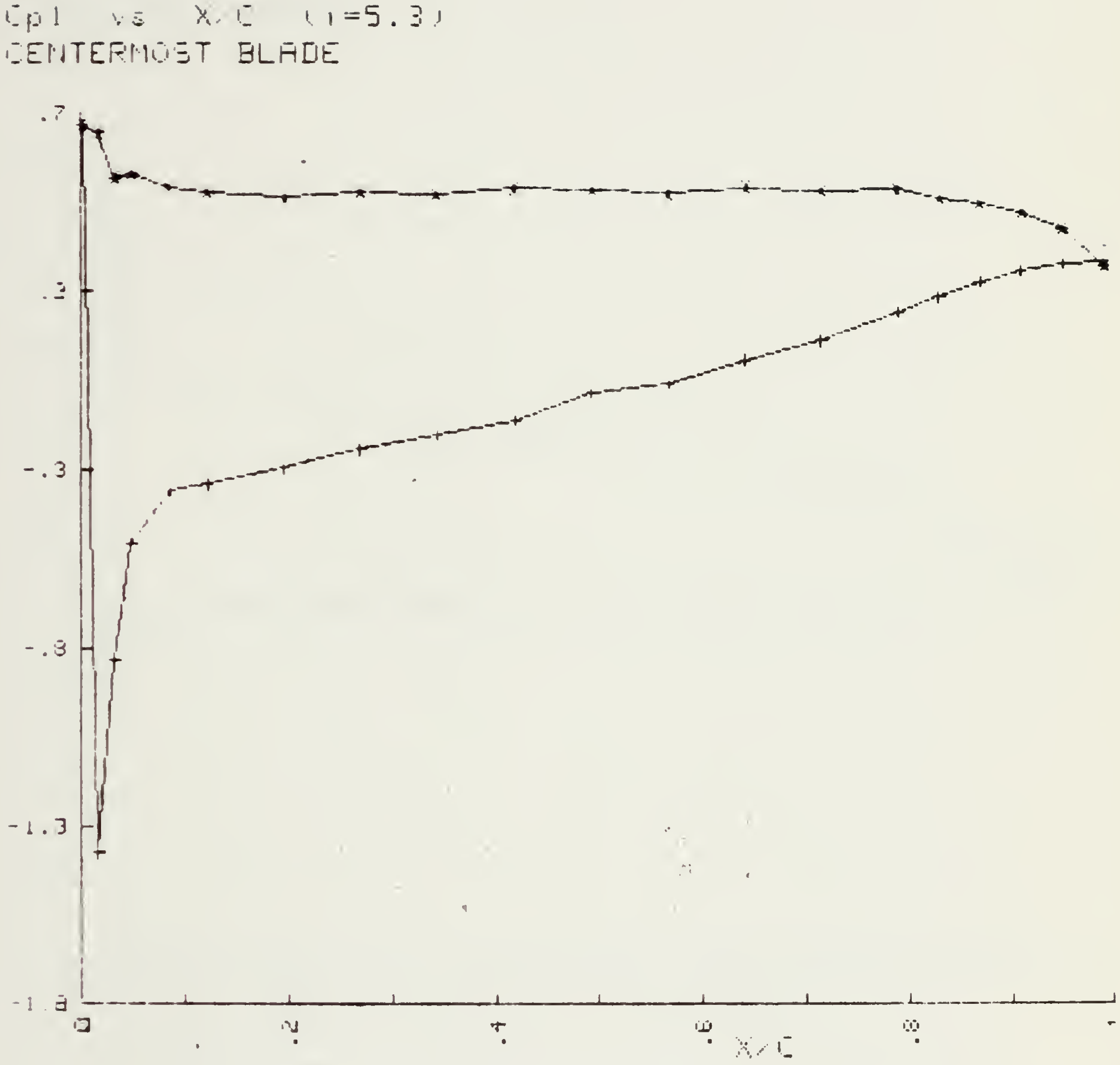


Fig. 59. Measured Blade Surface Pressure Distribution
(i = 5.3, * = Pressure Side,
+ = Suction Side)

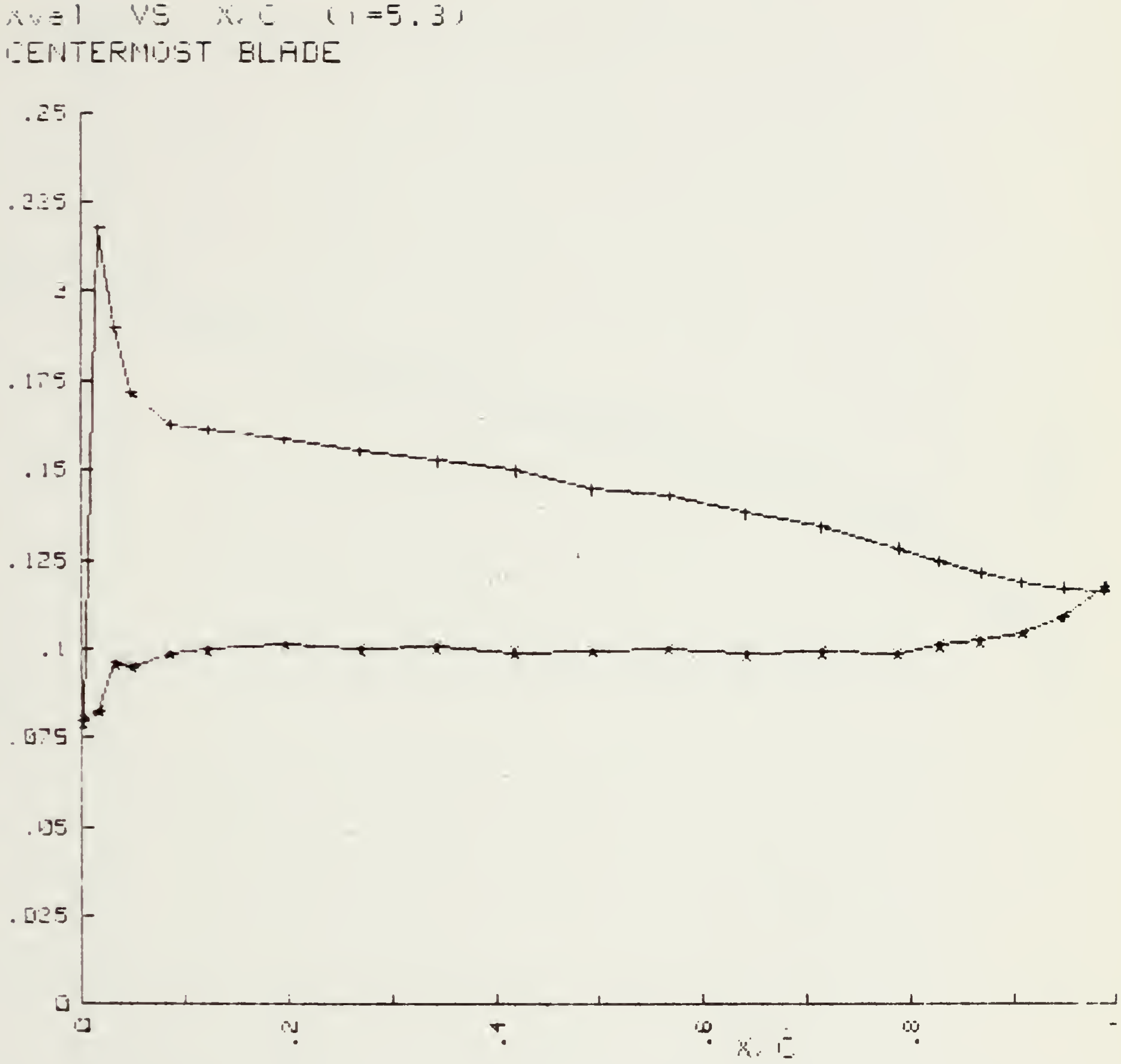


Fig. 60. Measured Blade Surface Velocity Distribution
(i = 5.3, * = Pressure Side,
+ = Suction Side)

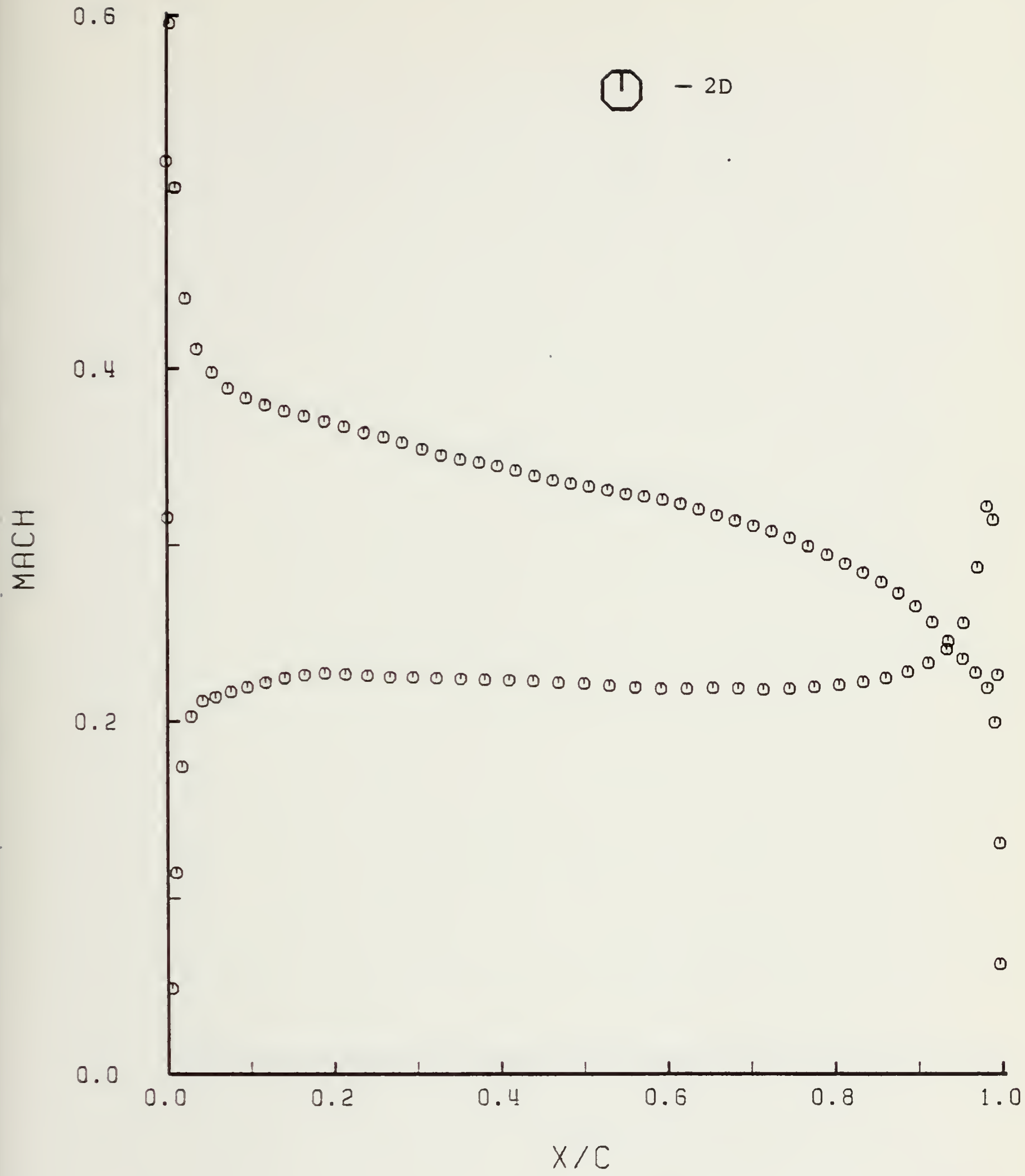


Fig. 61. 2D Code Blade Surface Mach Number Distribution (i = 5.3)

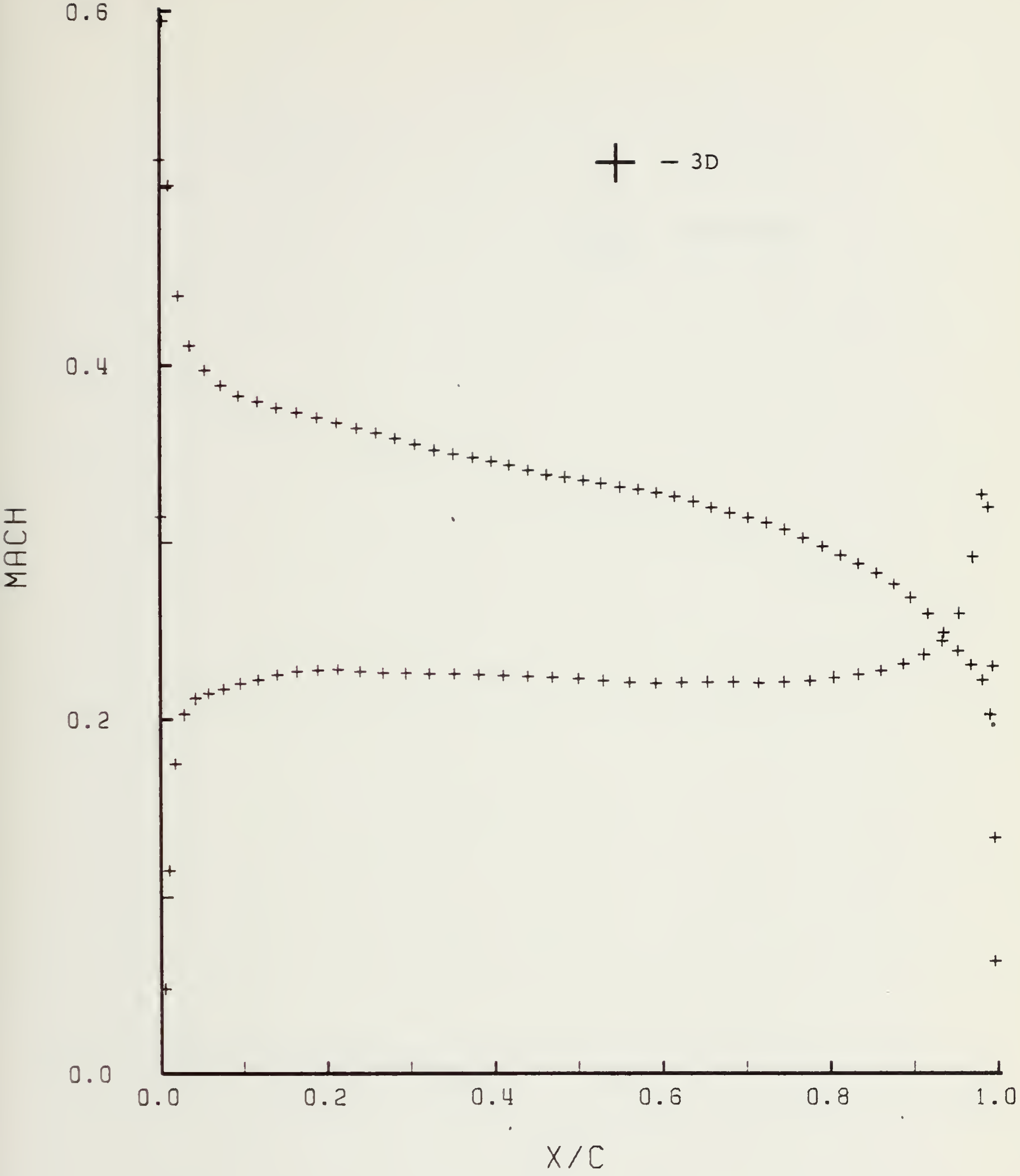


Fig. 62. 3D Code Blade Surface Mach Number Distribution (i = 5.3)

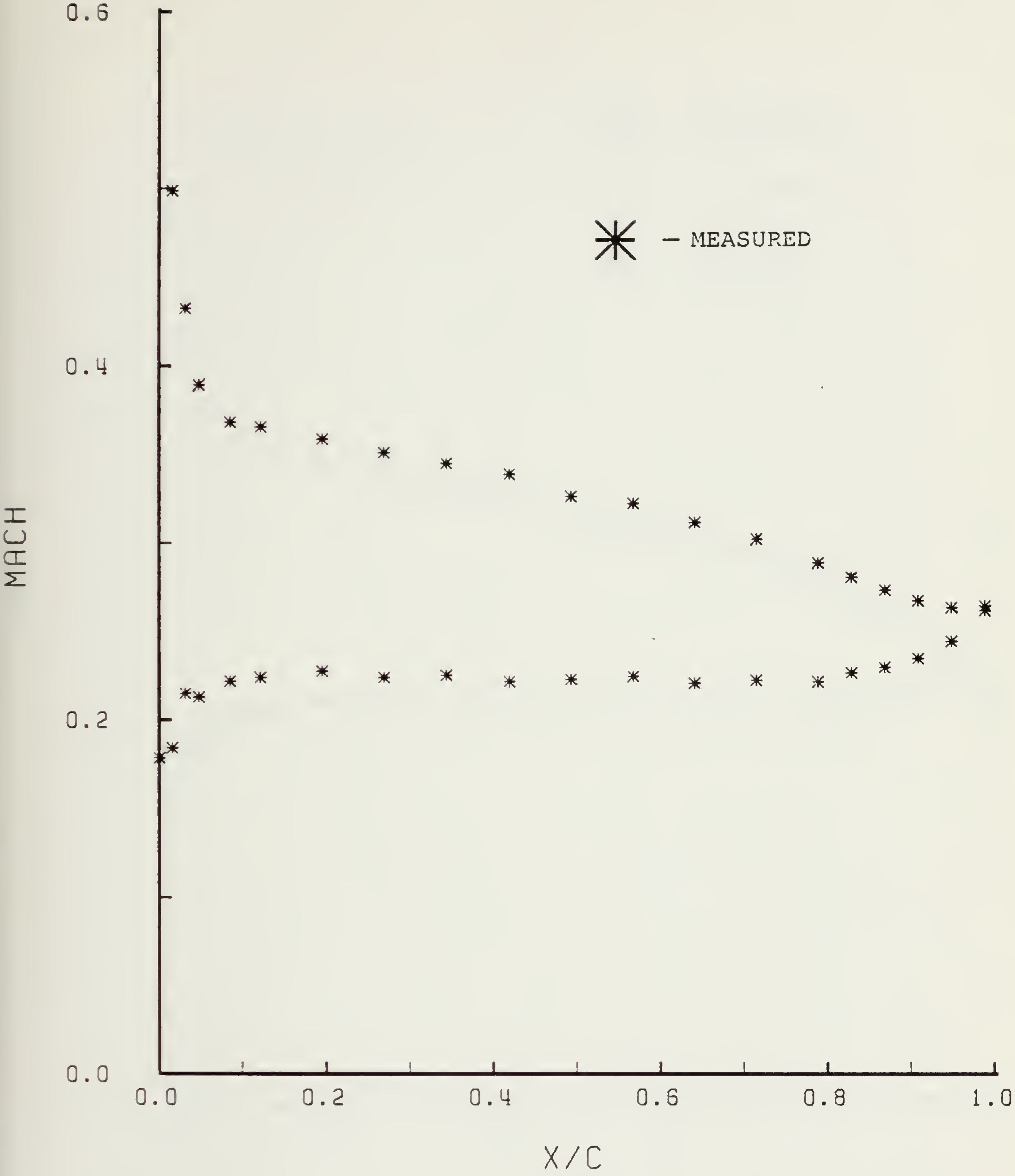


Fig. 63. Measured Blade Surface Mach Number Distribution (i = 5.3)

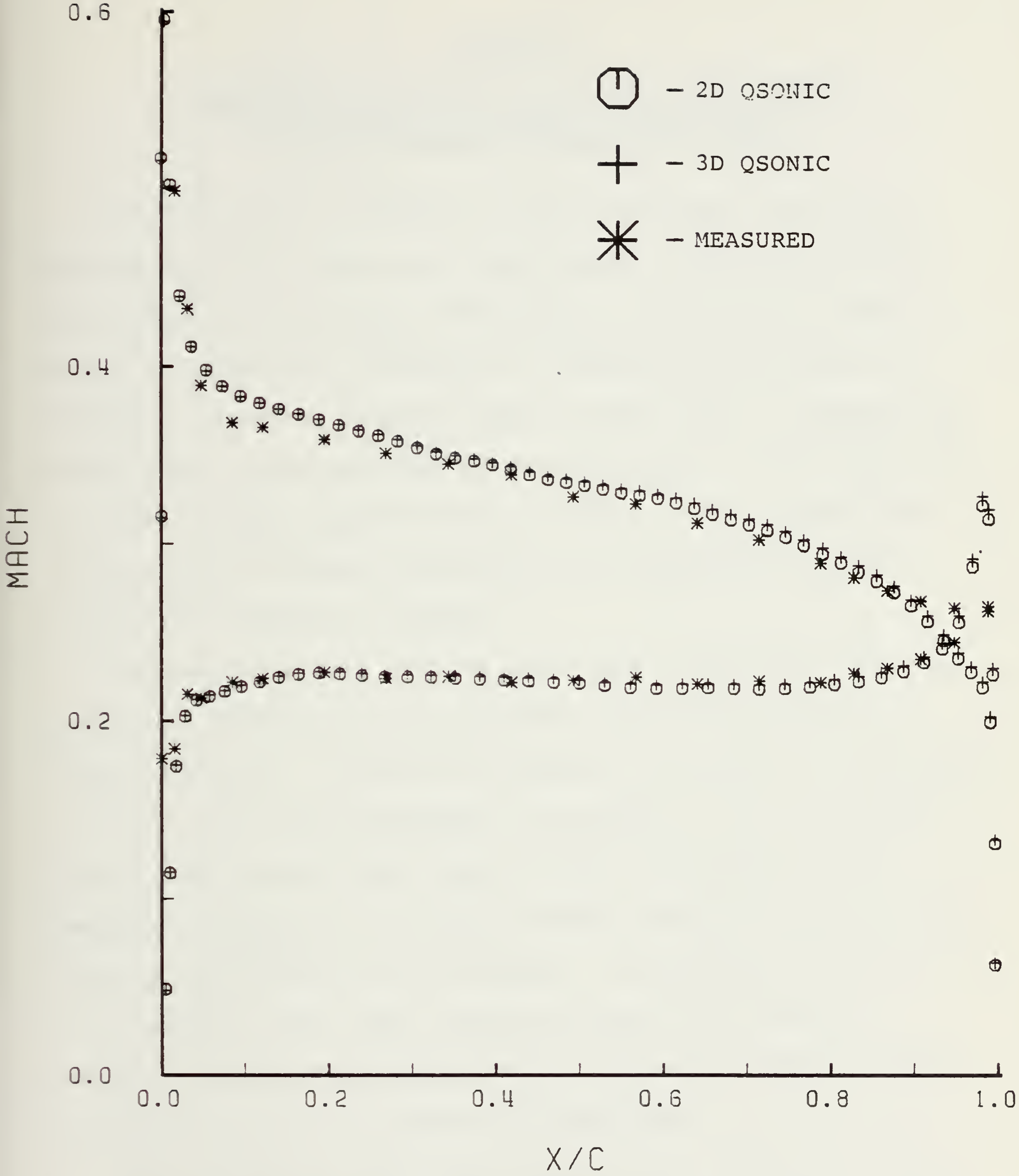


Fig. 64. Blade Surface Mach Number Distribution (i = 5.3)

APPENDIX A

MODIFICATION TO THE INLET GUIDE VANE SECTION OF THE SUBSONIC CASCADE WIND TUNNEL

As discussed in Section I, Cina discovered during his test program that while the inlet flow to the test section was uniform in direction and uniform in wall static pressure, it contained a variation in velocity and stagnation pressure resulting from the wakes of the IGV's. Because the inlet guide vanes were spaced at intervals of two inches and the test cascade blades spaced at three inches, departures from strictly periodic conditions were detected from one test blade passage to another.

To alleviate this problem, the inlet guide vane arrangement was modified so that the guide vanes were placed at 1 inch intervals. In order to preserve the option of reverting to a two inch IGV arrangement and because it was not possible to machine the south wall to hold additional blades, a separate structure was placed between the bell mouth contraction and the walls of the cascade. By mounting the IGV's in a separate unit which remained fixed once installed, hardware adjustments between tests associated with a change of end wall angle were greatly simplified.

The new inlet guide vane assembly was constructed using two lengths of 10 inch steel channel as shown in Fig. A.1.

One set of guide vanes was mounted on the south side of the unit at 2 inch spacings. A second set of vanes was mounted at 2 inch spacings on the north side of the unit. When the unit was assembled the guide vanes mounted from alternate sides meshed, resulting in an inlet guide vane spacing of 1 inch. The unit was provided with a single hand crank at the east end so that the vanes would be adjusted in unison. Once installed the complete structure could be left in place when the cascade north wall was removed to adjust air inlet angle. The one inch vane spacing ensured that periodicity at the test section would result for any test blade spacing which was a multiple of 1 inch. Equally important, the wakes remaining at the inlet to the test cascade would be greatly reduced as a result of closer spacing.

Figure A.1 shows the details of the inlet guide vane unit, while Fig. A.2 shows the assembly in relation to the bellmouth contraction and the side walls. Figure A.3 shows the mechanism to adjust the inlet guide vanes. Figure A.4 shows a view of the IGV assembly from the north side. A view of the Cascade Wind Tunnel partially assembled (north side wall off) is shown in Fig. A.5.

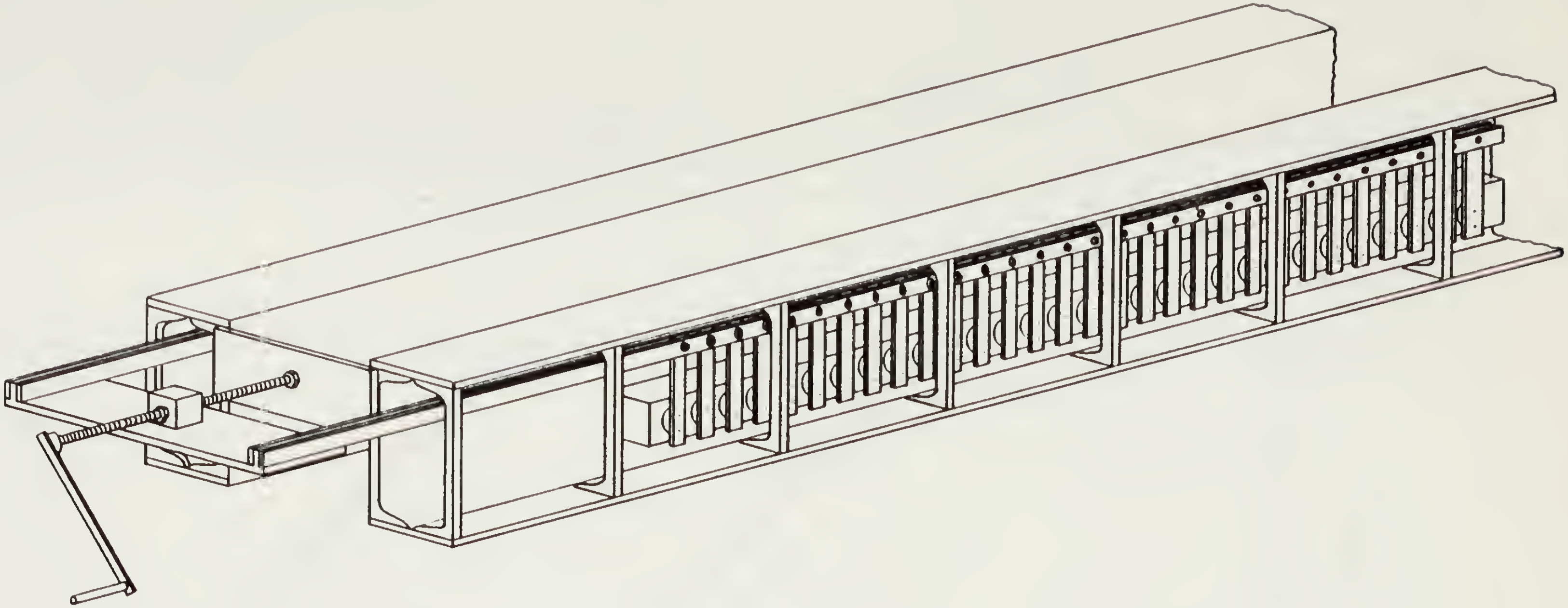


Fig. A.1. Inlet Guide Vane Assembly

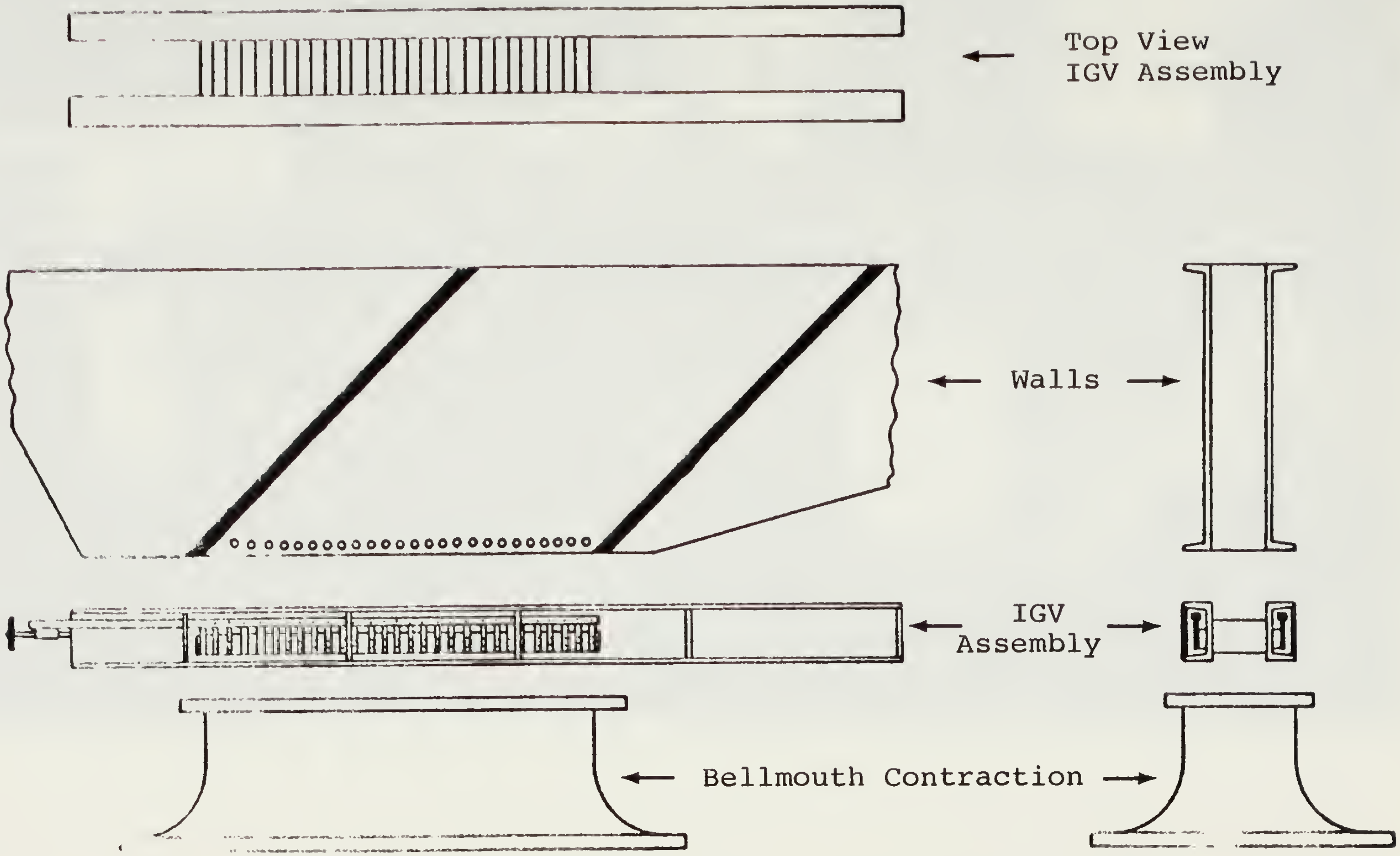


Fig. A.2. Cascade Wind Tunnel Sub-Assemblies

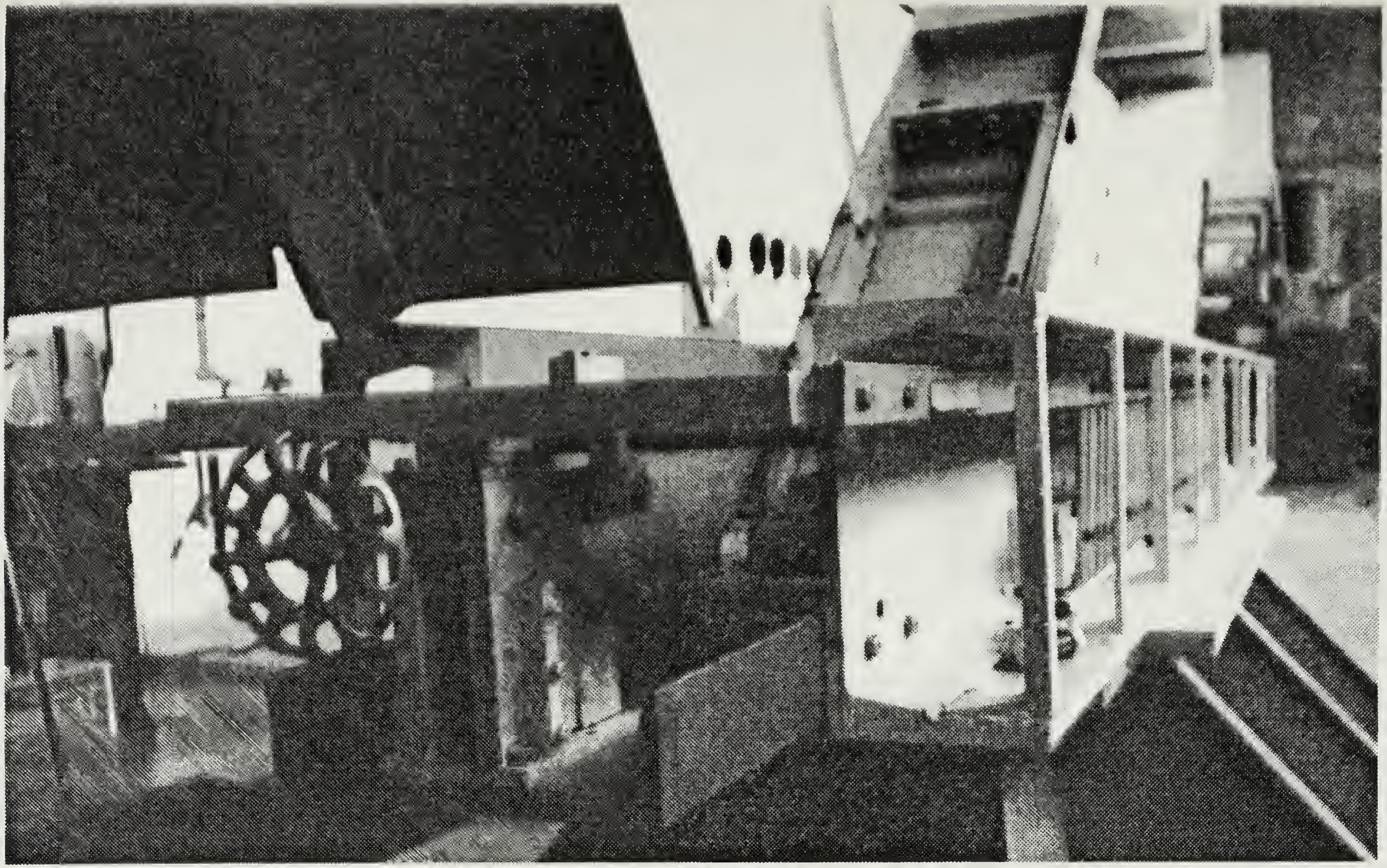


Fig. A.3. View of the IGV Adjustment Mechanism

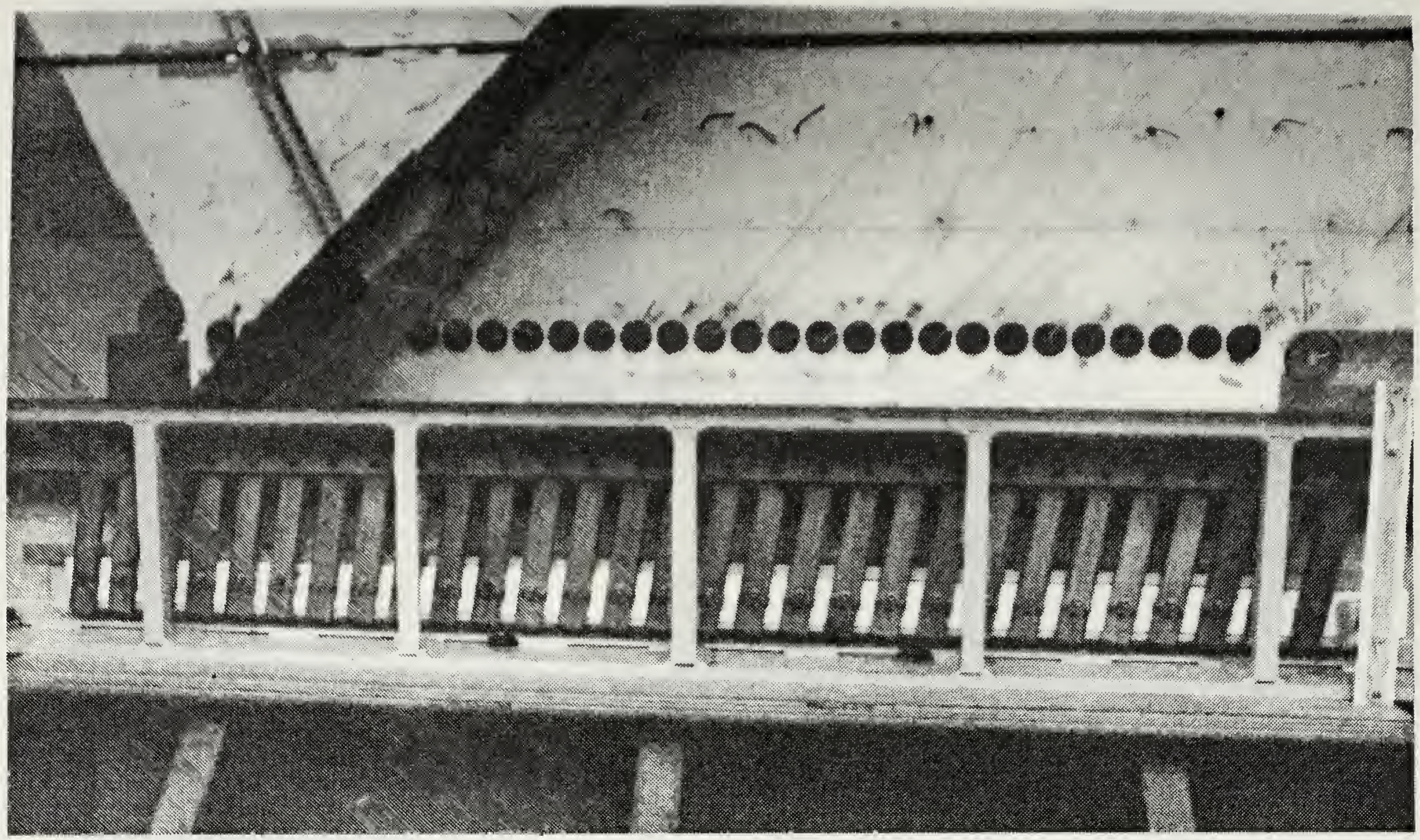


Fig. A.4. Side View of the IGV Assembly

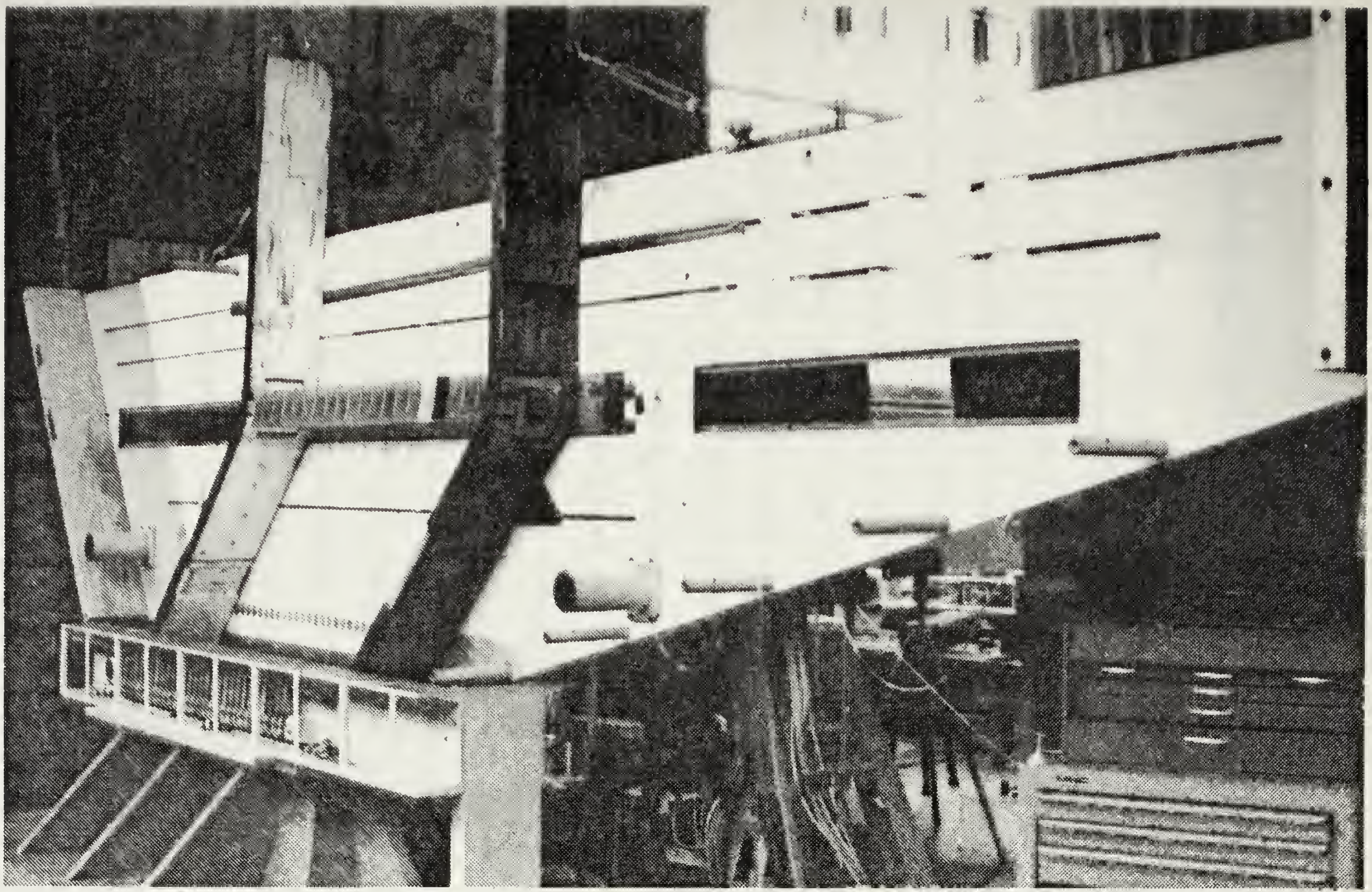


Fig. A.5. View of the Subsonic Cascade Wind Tunnel (North Wall Removed)

APPENDIX B

SELECTION AND INSTALLATION OF SCREEN MATERIAL

Pankhurst and Holder [Ref. 17] show that the turbulence of an airstream can be increased by placing a coarse mesh across the flow upstream of the test section. One of the most effective methods which is used for the reduction of turbulence and non-uniformities also consists of placing a mesh screen across the tunnel. Screens used for this purpose are of a finer mesh and are placed at a greater distance from the test section, and normally in the low-speed region upstream of the contraction in a conventional subsonic wind tunnel. By using such a screen the large scale eddies are removed at the expense of the introduction of a greater number of smaller eddies which decay rapidly.

McEligot [Ref. 16] investigated the possibilities of reducing non-uniformities in the test section of the subsonic cascade wind tunnel. His investigation and recommendations were completed while the inlet guide vanes were still at 2 inch spacings. McEligot concluded that some modification was necessary to achieve one percent uniformity for the mean velocity at the test cascade inlet plane and suggested several options. One of the options suggested was placing the turning vanes (inlet guide vanes) at a closer pitch. As explained in Appendix A, the pitch of the inlet

guide vanes was reduced from 2 inches to 1 inch. This new inlet guide vane arrangement did result in a one percent uniformity for the mean velocity at the test cascade inlet plane.

The other approach suggested was the use of wire gauze screens. McEligot showed that the velocity distribution appeared to be largely dependent on a pressure drop coefficient K, defined by the equation

$$K = \frac{p_1 - p_2}{\frac{1}{2} \rho V^2}$$

where p_1 and p_2 are the pressures upstream and downstream of the screen respectively. This pressure drop coefficient depends mainly on the blockage coefficient β defined by the equation

$$\beta = (1 - d/\ell)^2$$

where d is the diameter of wire used in the screen and ℓ is the distance between the wires. This blockage coefficient is commonly referred to as "percent open area" in catalogues of industrial wire cloth and woven wire screens.

For the velocities and flow angles used in the cascade wind tunnel, McEligot recommended using a wire gauze screen with a resistance coefficient, K, of 2.2 and a blockage coefficient, β, of 0.47. However, since the new inlet guide vane arrangement resulted in a one percent uniformity for

the mean velocity and the pressure drop across a screen with a blockage coefficient of 0.47 was expected to be higher than could be tolerated for the desired test conditions, screens with a slightly higher blockage coefficient (higher percent of open area) were selected to be tested.

The screens tested were of the following configurations:

MESH	WIRE DIAMETER (inches)	BLOCKAGE COEFFICIENT
4	.0410	.6989
5	.0410	.6320
16	.0105	.6922

Until the effectiveness of wire gauze screen in reducing non-uniformities in this facility was proven, a temporary installation of the screen material was considered adequate for testing purposes. The test screen was installed in the cascade wind tunnel by placing it between the inlet guide vane assembly and the north and south end walls. This arrangement placed the screen 7.25 inches downstream of the inlet guide vanes and 19.3 inches upstream of the lower test plane. Figure B.1 shows the installation of the wire gauze screen.

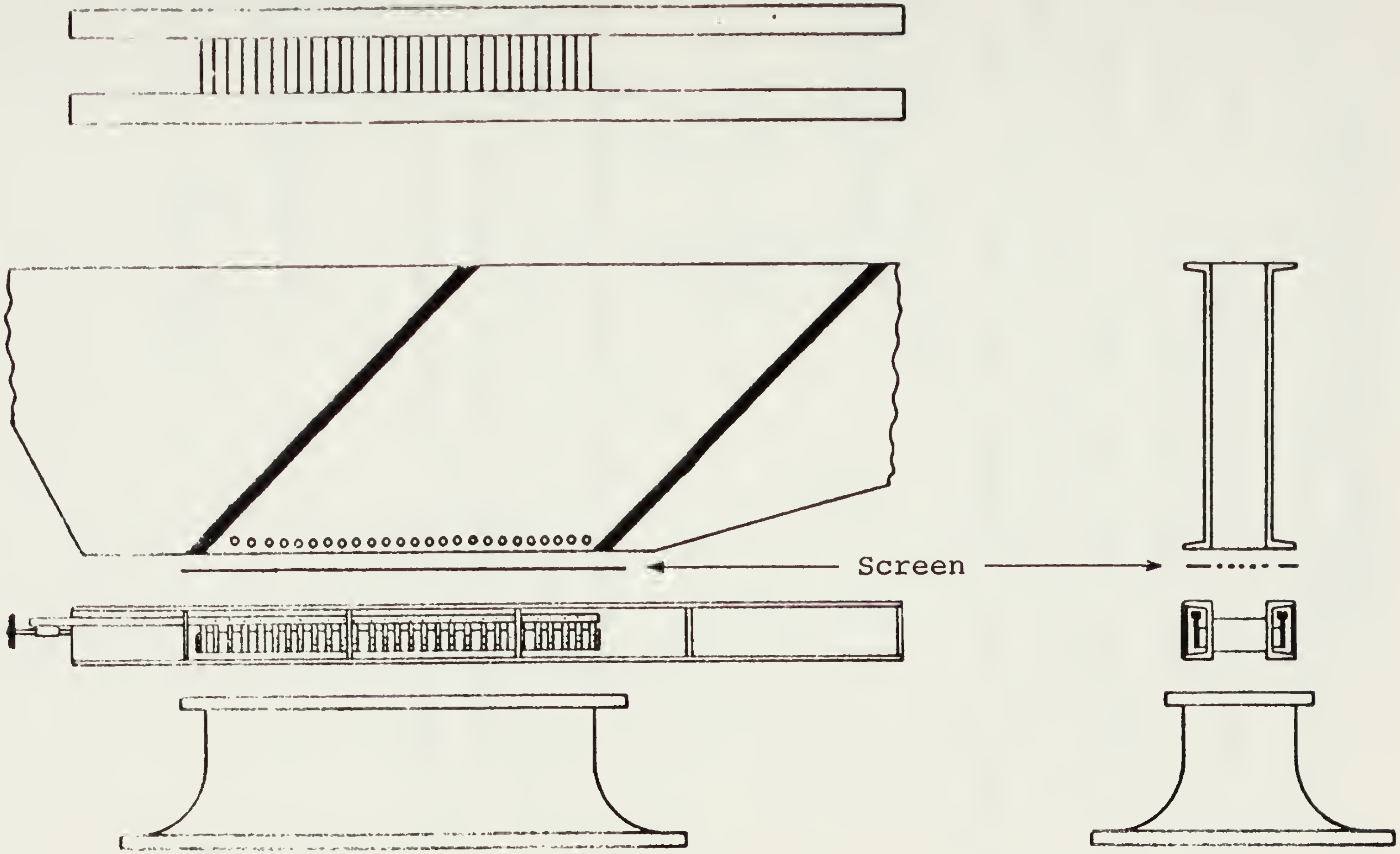


Fig. B.1. Screen Installation

APPENDIX C

CASCADE PERFORMANCE PARAMETERS

(by F. S. Cina; reproduced with minor changes from Ref. 7)

The performance of a cascade is specified in terms of the deviation angle (δ) and the loss coefficient ($\bar{\omega}$) for given inlet conditions. In Ref. 1 the loss coefficient is shown to correlate in terms of the Diffusion Factor (D). In the present work, the performance parameters were calculated using the following expressions:

1. Loss Coefficient ($\bar{\omega}$)

$$\bar{\omega} = \frac{\bar{C}_{p_{t_1}} - \bar{C}_{p_{t_2}}}{\bar{C}_{p_{t_1}} - \bar{C}_{p_1}} \tag{1}$$

where the mass averaged pressure coefficients in Eq. (1) are defined in Appendix C of Ref. 7. It is shown in Appendix C of Ref. 7 that the effect of time dependent supply conditions are removed and the effect of AVDR is included in the use of Eq. (1).

2. Diffusion Factor (D)

$$D = 1 - \frac{W_2}{W_1} + \frac{\Delta W_u}{2\sigma W_1} \tag{2}$$

3. Pressure Rise

$$C_{p_{static}} = \frac{\bar{P}_2 - \bar{P}_1}{\bar{Q}_1} \tag{3}$$

4. Blade Surface Pressure Coefficients

$$C_{p1} = \frac{P_s - \bar{P}_1}{\bar{Q}_1} \tag{4}$$

$$C_{p2} = \frac{P_s - \bar{P}_2}{\bar{Q}_2} \tag{5}$$

5. Dimensionless Velocity

$$X = \frac{V}{V_t} = \frac{V}{\sqrt{2C_pT_t}}$$

where V is the local velocity, $V_t = \sqrt{2C_pT_t}$ is the "limiting" velocity and T_t is the stagnation temperature.

APPENDIX D

INSTRUCTIONS FOR PREPARING INPUT AND OPERATING QSONIC USING A RECTILINEAR CASCADE CONFIGURATION

D.1 BACKGROUND INFORMATION

QSONIC has the capability to calculate an axial, mixed or radial flow field and the test cascade can be rotating or stationary. The geometry of the streamsurface can be a 2D planar cascade or axisymmetric with varying channel thickness and radial position. The capabilities of QSONIC, beyond those of previous cascade analysis methods (such as described in Ref. 8) include the ability to calculate through weak shocks with a peak relative Mach number less than 1.4, and completely around both leading and trailing edge regions of a blade profile. The blade shapes in the leading and trailing edge regions are not restricted to circular arcs. Detailed instructions for preparing input for a configuration other than an axial flow, stationary and rectilinear cascade may be found in Ref. 9. What follows are instructions for preparing the input applicable to the Rectilinear Cascade facility and running QSONIC on the Naval Postgraduate School's computer and associated operating system. It is assumed that the reader has a working knowledge of the NPS computer operating system and is familiar with Refs. 13 and 14.

QSONIC operates in two parts. The first part generates a body (blade) centered mesh (geometry generation). The second part actually solves for the flow conditions at points in the mesh (flow solution). The data necessary to generate a mesh consists of a two-dimensional description of the blade shape. This is in the form of pairs of (X,Y) points on the surface, together with parameters that describe the cascade layout, such as chord and stagger angle. Additionally, parameters describing the density of mesh lines complete the input for the geometry generation.

For flow field calculations, the upstream flow conditions, convergence criteria and a schedule of meshes to be used should be input. If quasi-three dimensional effects are to be considered, a data file containing a description of the streamchannel's radial thickness and position as a function of distance along the stream surface is needed. For the case described herein, this was input by assuming a linear reduction in streamchannel thickness using a factor of 1/AVDR. This gave excellent results. (The output of another NASA code, Meridl [Ref. 15], can be used to input data to QSONIC for compressor flow field calculations. This program has recently become operational on the NPS computer.)

The output of QSONIC consists of listings which contain an echo print of the input data, generated mesh coordinates on the blade surface, progress reports on the flow convergence and a list of the final velocities, pressures

and densities on the blade surface for each grid that was included in the schedule of solution meshes.

D.2 INPUT DESCRIPTION

The input for QSONIC falls into the following categories:

- Logical and case control parameters (NAMELIST PARAMS)
- Bulk data input:
  - For geometry generation runs (NAMELIST INSTUFF)
  - For flow solution runs:
    - Mesh point storage files
    - Streamchannel data file (for quasi-3D)

The following is a description of the logical and case control parameters for the Rectilinear Cascade. Except for TITLE, the format for all these variables is in namelist form. The namelist is PARAMS. This information is taken from Ref. 9 and adapted to the Cascade Wind Tunnel. Namelist variables can be entered in any order. If a default value is listed, it is not necessary to enter that particular variable. If the default value is listed as none, then a value for that parameter must be input.

The following parameters apply to both the mesh generation and the flow solution runs, but the values need not be the same.

Variable Name	Type	Default Value	Description
TITLE	Alphameric	None	This is a one-line name for the case being run. TITLE must appear on the first line of the data file that will be referred to as NAMELIST DATA.
NOFLOW	Logical	False	NOFLOW = .TRUE. if a run is to stop after generating a mesh, such as the mesh generation run. NOFLOW = .FALSE. for the flow solution run.
MS	Integer	None	MS is an array (max. dimension 10) of values (max. value = 25) for the number of grid lines in the mesh that will enclose the blade. 25 is a satisfactory number for blades of solidity near unity. As solidity increases the maximum value in MS should decrease.
NOZES	Integer	None	NOZES is an array (max. dimension 10) of values (max. value = 49) for the number of grid lines in the mesh radiating from the blade on one surface. If a value of NOZES is greater than zero, a mesh with that many lines will be developed and stored in the file MESHGEN DATA. If the value is negative, QSONIC assumes that this MESH already exists in the file MESHGEN DATA and will be read in. For Geometry Generation runs NOZES > 0 and for flow solution runs NOZES < 0. For electrostatic analog grid generator, NOZES must be odd.

BETA1	Real	None	BETA1 is the flow angle at the upstream boundary, in degrees. BETA1 is measured from the aerodynamic chordline to the direction of flow; clockwise is negative. This can be obtained from the output of the cascade tunnel data reduction program 'CX4431'. It is listed as "inlet air angle." Because of a difference in definition, it is necessary to use the usual inlet air angle minus the stagger angle for BETA1. Example: The output of CX4431 lists an inlet air angle of 42.429°. The cascade is configured with a stagger angle of 14.27°. 42.429° - 14.27 28.16 = BETA1
BETA2	Real	None	BETA2 is the flow angle at the downstream boundary in degrees. It is measured from the aerodynamic chordline to direction of flow. Clockwise is negative. This can be obtained from the output of the cascade tunnel data reduction program 'CX4431'. It is listed as outlet air angle. Because of a difference in definition, it is necessary to use the outlet air angle minus the stagger angle for BETA2.
GAMMA	Real	1.4	This is the ratio of specific heats. For the Subsonic Cascade Wind Tunnel the default value works well.
TOLS	Real	None	This is an array of dimension 10 of tolerances corresponding to MS and NOZES. Each grid solution will proceed until its TOLS value is satisfied.

MESH1	Integer	1	This is an index in the arrays MS and NOZES of the first mesh to be generated and/or used for the flow solution. For geometry generation runs, MESH1 selects one of the grids to be stored, provided NOZES(MESH1) > 0.
MESHN	Integer	None	This is an index in the arrays MS and NOZES of last grid to be calculated for geometry generation runs or used for the flow solution. For geometry generation runs, MESHN = MESH1. Subsequent flow solution runs then solve the case for all grids listed in MS and NOZES between index MESH1 and MESHN. For flow solution MESH1 normally points to the coarsest mesh. To insure equal spacing of grid lines over the entire mesh, $\frac{\mathrm{NOZES(I)} - 1}{\mathrm{K(I - MESH1)}} = \mathrm{Integer},$ where MESH1 $\leq$ I $\leq$ MESHN and K = 2, 3, 4, . . . (K = 2 if grid lines are doubled between successive grids).
LAMDA0	Real	None	Stagger angle of the blade row in degrees measured from the throughflow direction to the blade chord line. (Clockwise is negative.)
CHORD	Real	None	True chord of the blade, in the same units as the blade coordinates.
S	Real	None	Blade spacing in the same units as the blade coordinates.

The following parameters are required only for the geometry generation run. QSONIC gives the user a choice of two grid (mesh) generators. The Electrostatic Analog grid generator is applicable to any blade shape and any value of stagger or turning. The interpolation scheme grid generator works for most blades except those with sharp leading edges where the edge radius is less than .5% of chord. The interpolation scheme allows the user to concentrate grid lines in areas of high interest around the blade. With the Electrostatic Analog grid generator no concentration of grid lines is available. For the cascade configuration used in this study, the interpolation scheme provided gross errors in the flow solutions, so the Electrostatic Analog grid generator was used with good results.

Name	Type	Default	Description
NED	Integer	None	Total number of body definition coordinates that are input. These are the X,Y points that describe the profile of the blade, with the first point repeated as the last point.
KN	Integer	None	KN is used to indicate which grid generator is to be used. KN = 0 will call the electrostatic analog grid generator. For interpolation scheme, KN = number of body points on upper surface from the minimum to maximum X points, inclusive.

NED and KN are required for either grid generator. If the electrostatic analog grid generator is used, no other

parameters are used. If this grid generator is used the value from NOZES that is used must be odd.

The following parameters are used only if the Interpolation Scheme is used to generate the mesh.

Name	Type	Default	Description
RLE	Real	None	RLE is the leading edge radius of the blade, with units the same as the coordinates defining the blade profile.
RTE	Real	None	RTE is the trailing edge radius of blade.
THETL	Real	0	THETL is the camber angle of the leading edge in degrees. It is measured from the aerodynamic chord to the line tangent to the mean camber line at the leading edge; clockwise is positive.
THETT	Real	0	THETT is the camber angle at the trailing edge in degrees. It is measured from the chord line to the mean camber line at the trailing edge. Clockwise is positive.
CAMPER	Integer	6	For blades whose chordline lies outside the blade profile, such as the DCA blading discussed in this report, extra grid lines surrounding the blade are needed to interpolate the blade position. The truncated value of MS( )/CAMPER is added to MS( ). The maximum allowed value of MS( ) + MS( )/CAMPER is 30 grid lines. These are the grid lines that enclose the blade profile.
STABAC	Real	0.999	STABAC is used only for test cases where no blade shape is to be input. Default value is usually adequate.

CHOP	Real	0.99	If leading edge or trailing edge radius is less than 2% of chord consult Ref. 9 for clarification. Normally, $0.9 < \text{CHOP} < 1.0$.
SMOOTH	Logical	False	For automatic addition of more blade definition points in the region of the leading and trailing edges set SMOOTH = .TRUE. This should be done for all blades except cusps and wedges.
LEONLY	Logical	False	LEONLY = .TRUE. for smoothing about the leading edge only; this is used if the trailing edge is a cusp or a wedge. SMOOTH must also be .TRUE.
SLP1	Real	1	These parameters control the concentration of grid lines, if desired. The default values worked well for the DCA blades reported herein. For controlling the amount and location of the concentration consult Ref. 9.
SLP2	Real	2	
SLP3	Real	1	
SLP4	Real	1	

The following logical and case control parameters are required only for flow solution runs.

Name	Type	Default	Description
MINF	Real	None	This is the Mach number at the upstream boundary. This can be determined from the non-dimensional velocity X output from the cascade tunnel data reduction program 'Redd 5' and the relationship, $\frac{\gamma - 1}{2} M^2 = \frac{X^2}{1 - X^2}$ which yields $M = \left\{ \frac{X^2}{1 - X^2} \cdot \frac{2}{\gamma - 1} \right\}^{\frac{1}{2}}$

TOLS(I) is the tolerance for MS(I) and NOZES(I). There are three forms of input permitted.

A) -1.0 < TOLS(I) < 0.0: Calculations of the flow solution will proceed until the relative circulation error

$$\left| \frac{C^{N}_{CALC} - C_{EXACT}}{C_{EXACT}} \right| < |\mathrm{TOLS(I)}|$$

TOLS values between -10^{-3} and -10^{-6} are typical values for grids. This method of input is appropriate only for lifting (non-symmetric blades) cases.

B) 0.0 < TOLS(I) < 1.0: Calculations of the flow solution will proceed until the average relative change in potential is less than the absolute value of TOLS(I).

$$\left(\frac{\delta\phi}{\phi}\right)_{AVE} < |\mathrm{TOLS(I)}|$$

Typical values should be between 10^{-3} and 10^{-5}.

C) 1.0 < TOLS(I): Calculations proceed until the number of iterations equals TOLS(I).

Regardless of TOLS input, the solution for each grid will stop after 300 iterations if the TOLS criteria has not yet been made. All three forms were used for the cascade configuration reported herein with no discernible differences in results.

OVEREL	Real	1.5	The default values of these parameters are adequate for flow conditions in the subsonic cascade wind tunnel.
UNDERL	Real	1.0	
SUPREL	Real	1.0	
NOWREL	Integer	20	
NOTYET	Integer	2	
TEGARD	Real	2.0	
DAMP	Real	1.0	
CII	Real	0.2	
IT	Integer	10	Number of iterations between intermediate printouts of residuals and Mach number. The information controlled by this parameter is of limited value in comparing with measured data, so a value greater than 10 reduces the amount of computer printout. For the study reported herein 40 was used.
ALLOUT	Logical	.FALSE.	To list the flow quantities at all grid points in the last mesh set ALLOUT = .TRUE.. Unless a very coarse grid is used, the output resulting from ALLOUT = .TRUE. would be extremely voluminous and of limited value. Until the cascade is configured so it is possible to take data from between the blades, ALLOUT should be .FALSE..
QUASI3	Logical	.FALSE.	QUASI3 = .TRUE. to activate streamchannel thickness and/or radius variations. The cascade wind tunnel has no radius variations, but to simulate 3-D effects the streamchannel thickness is reduced at the exit boundary by a factor of 1/AVDR. This data is placed in a file used by QSONIC if a quasi 3-D solution is desired.
NSTRM	Integer	1	This is the position of desired streamsurface data on the streamchannel file used if QUASI3 = .TRUE.. Currently the default value of 1 identifies the proper streamsurface data

			in the streamchannel file. If the output from the NASA code 'Meridl' is used for the streamchannel data, then by using different values of NSTRM, different streamsurface data may be used.
RINF	Real	1.0	This is the spanwise radius at the upstream boundary divided by aerodynamic chord. Radius effects are activated if RINF ≠ 1.0. The current version of QSONIC allows the following cases.

QUASI	RINF	Results
1) .FALSE.	1.0	Planar 2D flow
2) .TRUE.	≠ 1.0	Thickness on file; radius on file.
3) .TRUE.	1.0	Thickness on file; constant radius.

Only 1) and 3) apply to the cascade wind tunnel.

WAKE	Real	0.0	These parameters apply only if the test cascade is rotating and/or the downstream Mach is near 1.0.
MINF2	Real	10.0	
OMEGA	Real	0.0	
VAXIAL	Real	999.0	
FLOCO	Real	999.0	

At this point all of the logical and case control parameters necessary to use QSONIC for the flow conditions possible in the subsonic cascade wind tunnel have been discussed. The following is a description of the Bulk Data input for the geometry generation run and the flow solution run.

The format for all variables in the bulk data for mesh generation (geometry) is namelist form. The namelist is INSTUFF.

Name	Type	Default	Description
H2	Complex	None	This is a table of points defining the blade profile. The real part = X, and imaginary part = Y coordinate. The table begins at the point of maximum X value at the trailing edge and proceeds clockwise back around to the first point, which is repeated. The blade must be at the stagger angle and the origin at the point of minimum X. For Electrostatic Analog grids, the stagger angle must be positive (leading edge low, trailing edge high). The maximum number of points in H2 is 99 for the interpolation scheme or 63 for the Electrostatic Analog.
BUG2	Logical	.FALSE.	BUG2 = .TRUE. for a more detailed output of geometry generation. This will include the X,Y coordinates that define the mesh as well as second derivatives at grid points on the body. Except for trouble shooting this data is of limited value at the present time since there is no graphic output.

The bulk data for flow solutions consists of a mesh file and the streamchannel data file if quasi-3D effects are to be calculated. The mesh file is created by QSONIC during the mesh (grid) generation run. No further inputs are required from the user for the mesh file.

The streamchannel data file must contain a table of streamtube thicknesses, radial positions and corresponding X values along the streamsurface.

Name	Type	Default	Description
CHO	Real	None	CHO is the aerodynamic chord multiplied by the cosine of LAMDA0. (LAMDA0 ≡ stagger angle)
NRSP	Integer	None	NRSP is the total number of data points in each of the tables of thickness, radial position, and X location. If NRSP is 2, a linear distribution is obtained between the endpoints given. NRSP = 2 was used for the study reported herein with good results.
RM	Real	None	Array of corresponding X locations for thickness and radius data values. X = 0 represents the leading edge of blade, with the blade at stagger angle. The units can be any consistent length scale common to CHO, RM, RMSP and BESP. Inches were used in this study.
RMSP	Real	None	Spanwise radial positions of streamsurface at the X locations given in RM. RMSP was not used in the current study.
BESP	Real	None	Array of streamtube thickness values at the X locations specified in RM. For the study reported herein, at X = 0 a streamtube thickness of 1.0 was arbitrarily selected. The streamtube contraction through the test section was similated by reducing the thickness at X = 0, by a factor of 1/AVDR at the trailing edge. Duval [Ref. 3] explains AVDR.

D.3 PREPARING INPUT FILES

QSONIC was originally configured to use several input/output devices while reading data and generating output. The input/output devices are listed below as used by QSONIC.

I/O Unit	Usage
2	File containing streamchannel data. This is used only if QUASI = .TRUE..
5	Standard card input; NAMELISTS PARAMS, INSTUF.
6	Standard printed output.
13	For mesh generation runs, coordinates of all mesh points are written here. For flow solutions, X, Y, velocities, pressures and MACH are recorded for graphic display. The program currently has no graphic output capability. No user action is necessary to create this file.
18	Used as temporary storage. No output is stored here. No user action is necessary in conjunction with this file.
23	Previously developed mesh coordinates are read in from this file during the flow solution. After a mesh generation run, the user must create this file and put in it the data from I/O unit 13, so that during the flow solution QSONIC can read in the mesh points.

QSONIC is presently configured to operate with the CMS system of the IBM 370 computer. This system provides a high degree of flexibility in parameter selection. With this system, all the input/output units previously mentioned are on the disk space assigned to the Turbopropulsion Laboratory (TPL). Access to QSONIC and the TPL disk space can be obtained through the Director of TPL.

The first step in using QSONIC is the creation of the data file necessary for the mesh generation run. This is done using the standard procedures of the XEDIT function of the CMS operating system. Reference 14 has specific instructions for creating new files. The filename and filetype for the data used in this study was NAMELIST GEOMD. Once the data file is opened, the necessary data is input beginning at column 2 of the virtual card. Since the variables are in namelist form, they can be input in any order.

Table D.1 is an example of the data file necessary for the mesh generation run. The TITLE must appear on the first line (FORMAT = 20A4). After the TITLE, the logical and case control parameters are input after the namelist &PARAMS. When all the case control parameters required are input the PARAMS namelist is closed with &END. On the next line of the data file the bulk data for the mesh generation run is input in namelist form, with the namelist &INSTUF. The H1 = 100*(0.0,0.0) that appears after &INSTUF on Table D.1 was used on earlier versions of QSONIC, but is not used in the present version. It should, however, appear in the data file before the H2 variables (X,Y coordinates defining the blade profile).

At this point, some discussion of the coordinates defining the blade profile is warranted. Table D.2 is a listing of the X and Y coordinates of the DCA blading used in this study. Figure D.1 is a plot of these coordinates.

Recall that the coordinates defining the blade profile for QSONIC must be for the blade at the stagger angle and minimum X at the origin. The coordinates of Table D.2 were translated and rotated using a coordinate transformation routine for the HP-67 programmable calculator. These new coordinates appear in the namelist INSTUFF on Table D.1. Figure D.2 is a plot of the translated and rotated coordinates. It is highly recommended that such a plot be made for any new blade profiles, to ensure that the original coordinates are translated and rotated properly.

The second step in using QSONIC is the creation of the data files necessary for the flow solution run. The file used for the flow solution in this report is on the TPL disk space with a filename/filetype of NAMELIST FLOWD. The simplest way to open this data file is to use the XEDIT function, as discussed in Ref. 14, to start a new file. Then input the same data as is in the data file for the mesh generation run using the XEDIT subcommand GET (filename) (filetype). The appropriate changes and additions can then be made to this file. Table D.3 is an example of the data file just discussed.

Two more data files are required for the flow solution. The data for one of these is created by the mesh generation run. The other file contains the streamchannel thickness data for implementing quasi-3D effects.

After the mesh generation run, a file with the filename/filetype MESHGEN DATA will appear on the disk. Create a new file with the filename/filetype MESHIN DATA. This is most easily done by issuing the command 'XEDIT MESHIN DATA'; then use 'GET MESHGEN DATA'. This file contains the previously developed mesh coordinates.

The streamchannel data file should have the filename/filetype of DATA5D DATA. The format for the data file is shown below.

Virtual Card	Column No.	Variable Name
1	BLANK	
2	BLANK	
3	21-30	CHO
4	BLANK	
5	36-40	NRSP
6	BLANK	
7	BLANK	
8		
9		
10		
11		
12 ↓ As needed	1-80 (8F10.5)	RM
↓ As needed	1-80 (8F10.5)	RMSP (not used in this study)
	1-80 (8F10.5)	BESP

Table D.4 is an example of the data file used in the present study. Since NRSP = 2 was used for this study a

linear distribution is assumed for the streamtube thickness values and only 2 values of RM and BESP are required; therefore, only 1 virtual card was required for each array.

D.4 PROGRAM OUTPUT

The output generated by QSONIC for the geometry generation run includes a printed listing (I/O unit 6) and a mesh point file (I/O unit 13). The printed listing under the CMS system I/O unit 6 is normally the computer terminal unless the command 'FILEDEF 06 PRINTER' has been invoked. It is unusual for the program to run properly the first time, so initially it is helpful to have the printed listing appear at the terminal. Once the program is running properly the output should be sent to the line printer.

The flow solution run output consists of a printed listing (I/O unit 6) and a plot data save file (I/O unit 13). Once the flow solution is running properly the printed listing should be sent to the line printer.

Table D.5 is an example of the output generated by the geometry generation run. Figure D.3 is a plot of the grid output points on the blade surface, horizontal chord, produced by the mesh generation run. Figure D.4 is a plot of the grid output points with the blade at the stagger angle. Table D.6 is an example of the output generated by the flow solution.

A detailed explanation of the printed output for the program QSONIC may be found in Ref. 9.

D.5 RUNNING THE PROGRAM

The files on the TPL disk space that apply to QSONIC are listed below:

QSONIC EXEC	A1
QSONIC FORTRAN	A1
QSONIC TEXT	A1
NAMELIST GEOM	A1
NAMELIST FLOW	A1
NAMELIST GEOMD	A1
NAMELIST FLOWD	A1
DATA5 DATA	A1
DATA5D DATA	A1

QSONIC EXEC sets the input/output devices required to read and store data. QSONIC FORTRAN is the source program. To document the changes to QSONIC necessary to use the code with the IBM 370 operating system and serve as a reference for future users, a program listing is included at the end of this appendix. QSONIC TEXT is the computer executable code created when QSONIC FORTRAN is compiled. NAMELIST GEOM and NAMELIST FLOW are the data files for the geometry generation and flow generation respectively for the example in Ref. 9. DATA5 DATA is the streamchannel data required for the quasi-3D solution for the example in Ref. 9.

NAMELIST GEOMD is the data file for the geometry generation for the DCA blading used in the study reported herein. NAMELIST FLOWD is the file for the flow solution for the cascade configuration used in this study.

QSONIC expects the input data to be in a file on the TPL disk space named NAMELIST DATA. Since the first time QSONIC is run is to develop the body centered mesh, the file NAMELIST GEOMD must be renamed NAMELIST DATA, using procedures specified in Ref. 13. Because QSONIC requires large amounts of virtual memory, extra storage must be defined for the code to operate. This is accomplished by issuing the command 'DEFINE STORAGE 1504K'.

With the data file renamed and more storage defined, type 'QSONIC' to load the program. The output will appear on the terminal screen unless FILEDEF 06 PRINTER was invoked prior to loading the program.

After the mesh generation is complete, rename NAMELIST DATA to NAMELIST GEOMD and change NAMELIST FLOWD to NAMELIST DATA. Create a data file with the filename/filetype MESHIN DATA. The elements of this file are the same as the elements in the file MESHGEN DATA that was created by the mesh generation run. The necessary input/output files are now configured for a flow solution run. Issue the command 'QSONIC' to begin execution.

If the program output appears at the terminal it is possible to have some I/O error messages appear with the

output. This is because the write statements in QSONIC are formatted for the 132 character long line of the printer. These errors do not affect the validity of the program output.

The explanation for any error or condition message generated by QSONIC can be found in Ref. 9.

D.6 QSONIC UPDATE

Recently an improved version of QSONIC was reported by NASA Lewis Research Center [Ref. 13]. The new version requires less virtual memory and executes approximately 30% faster than the version presently in use at NPS. Also, the output appears in a different format than is described in this appendix. Reference 18 describes the most recent version of QSONIC in detail.

TABLE D.1. INPUT DATA FOR MESH GENERATION RUN OF QSONIC

```
      NASA DCA BLADES, GEOMETRY GEN  42.4,5.3
&PARAMS NOFLOW=.TRUE.,RESTAR=.FALSE.,REMESH=4,
MS=3,5,10,15,NOZES=9,13,25,49,MESH1=4,MESHN=4,LAMDA0=14.27,
CHORD=5.01,S=3.0,NED=51,KN=0,RLE=0.44,RTE=0.44,
THETL=-45.72,THETT=45.72,CAMPER=5,STABAC=0.999,CHOP=0.99,
SMOOTH=.TRUE.,LEONLY=.FALSE.
&END
&INSTUF
H1=100*(0.0,0.0)
H2= (0.48554E+01, 0.12616E+01),(0.48095E+01, 0.12066E+01)
(0.47426E+01, 0.12102E+01),(0.45112E+01, 0.12153E+01)
(0.42827E+01, 0.12170E+01),(0.40545E+01, 0.12096E+01)
(0.38285E+01, 0.11975E+01),(0.36030E+01, 0.11793E+01)
(0.33812E+01, 0.11549E+01),(0.31591E+01, 0.11232E+01)
(0.29391E+01, 0.10879E+01),(0.27205E+01, 0.10467E+01)
(0.25038E+01, 0.9978),(0.22877E+01, 0.9428),(0.20745E+01, 0.8845)
(0.18621E+01, 0.8191),(0.16499E+01, 0.7486),(0.14402E+01, 0.6726)
(0.12322E+01, 0.5898),(0.10257E+01, 0.5011),(0.8201, 0.4045)
(0.6158, 0.3071),(0.4137, 0.2010),(0.2134, 0.882E-01)
(0.656E-01, 0.0),(0.0, 0.267E-01),(0.126E-01, 0.701E-01)
(0.1801, 0.2190),(0.3701, 0.3726),(0.5633, 0.5135),(0.7588, 0.6458)
(0.9584, 0.7657),(0.11592E+01, 0.8766),(0.13630E+01, 0.9759)
(0.15693E+01, 0.10655E+01),(0.17783E+01, 0.11486E+01)
(0.19897E+01, 0.12179E+01),(0.22017E+01, 0.12811E+01)
(0.24183E+01, 0.13341E+01),(0.26362E+01, 0.13782E+01)
(0.28562E+01, 0.14135E+01),(0.30795E+01, 0.14362E+01)
(0.33055E+01, 0.14524E+01),(0.35325E+01, 0.14565E+01)
(0.37639E+01, 0.14514E+01),(0.39971E+01, 0.14354E+01)
(0.42334E+01, 0.14109E+01),(0.44717E+01, 0.13704E+01)
(0.47147E+01, 0.13197E+01),(0.48232E+01, 0.12947E+01)
(0.48554E+01, 0.12616E+01),48*(0.0, 0.0)
BUG2= F
&END
```

TABLE D.2. TEST BLADE COORDINATES

X-COORD.	Y-PRESS.	Y-SUCT.
-0.044	0.000	0.000
-0.021	-----	0.039
0.013	-0.042	-----
0.178	0.007	0.142
0.400	0.067	0.244
0.622	0.120	0.333
0.844	0.164	0.413
1.067	0.207	0.480
1.289	0.242	0.538
1.511	0.271	0.584
1.733	0.293	0.620
1.956	0.309	0.649
2.178	0.320	0.664
2.399	0.324	0.673
2.622	0.324	0.671
2.844	0.318	0.660
3.066	0.304	0.640
3.288	0.284	0.607
3.511	0.260	0.567
3.732	0.229	0.515
3.955	0.191	0.453
4.177	0.147	0.380
4.400	0.098	0.298
4.621	0.040	0.200
4.844	-0.022	0.091
4.908	-0.042	-----
4.943	-----	0.040
4.966	0.000	0.000

TABLE D.3. INPUT DATA FOR FLOW SOLUTION RUN OF QSONIC

```
          NASA DCA BLADES, FLOW SOLUTION   42.4,5.3
&PARAMS NOFLOW=.FALSE.,RESTAR=.FALSE.,REMESH=4,
MS=3,5,10,15,NOZES=-9,-13,-25,-49,KN=0,NED=51,
MESH1=1,MESHN=4,LAMDA0=14.27,CHORD=5.01,
S=3.0,MINF=0.3127,BETA1=28.16,BETA2=-12.42,
GAMMA=1.4,TOLS=1.E+04,-2.E-05,7.E-05,6.E-05,-.000001,2*0.,
OVEREL=1.5,UNDERL=1.,SUPREL=1.0,NOWREL=20,NOTYET=10,
CII=0.40,IT=40,ALLOUT=.FALSE.,QUASI3=.TRUE.,NSTRM=1,
RINF=1.,WAKE=0.,MINF2=10.0,OMEGA=0.
&END
&INSTUF
H1=100*(0.0,0.0)
H2= (0.48554E+01, 0.12616E+01),(0.48095E+01, 0.12066E+01)
(0.47426E+01, 0.12102E+01),(0.45112E+01, 0.12153E+01)
(0.42827E+01, 0.12170E+01),(0.40545E+01, 0.12096E+01)
(0.38285E+01, 0.11975E+01),(0.36030E+01, 0.11793E+01)
(0.33812E+01, 0.11549E+01),(0.31591E+01, 0.11232E+01)
(0.29391E+01, 0.10879E+01),(0.27205E+01, 0.10467E+01)
(0.25038E+01, 0.9978),(0.22877E+01, 0.9428),(0.20745E+01, 0.8845)
(0.18621E+01, 0.8191),(0.16499E+01, 0.7486),(0.14402E+01, 0.6726)
(0.12322E+01, 0.5898),(0.10257E+01, 0.5011),(0.8201, 0.4045)
(0.6158, 0.3071),(0.4137, 0.2010),(0.2134, 0.882E-01)
(0.656E-01, 0.0),(0.0, 0.267E-01),(0.126E-01, 0.701E-01)
(0.1801, 0.2190),(0.3701, 0.3726),(0.5633, 0.5135),(0.7588, 0.6458)
(0.9584, 0.7657),(0.11592E+01, 0.8766),(0.13630E+01, 0.9759)
(0.15693E+01, 0.10655E+01),(0.17783E+01, 0.11486E+01)
(0.19897E+01, 0.12179E+01),(0.22017E+01, 0.12811E+01)
(0.24183E+01, 0.13341E+01),(0.26362E+01, 0.13782E+01)
(0.28562E+01, 0.14135E+01),(0.30795E+01, 0.14362E+01)
(0.33055E+01, 0.14524E+01),(0.35325E+01, 0.14565E+01)
(0.37639E+01, 0.14514E+01),(0.39971E+01, 0.14354E+01)
(0.42334E+01, 0.14109E+01),(0.44717E+01, 0.13704E+01)
(0.47147E+01, 0.13197E+01),(0.48232E+01, 0.12947E+01)
(0.48554E+01, 0.12616E+01),48*(0.0, 0.0)
BUG2= F
&END
```

TABLE D.4. DATA FILE FOR QUASI-3D SOLUTION

```
  STREAMLINE DATA FOR DCA1
                 4.8554
                                   2



    0.0   4.85500
1.00000   0.98476
```

TABLE D.5. SAMPLE OUTPUT FROM MESH GENERATION RUN

```
1 QSONIC VERSION 1.4.9.1            NASA DCA BLADES, GEOMETRY GEN  42.4,5.3
0     CASE CONTROL INPUT ECHO

 &PARAMS
 NOFLOW=T,RESTAR=F,REMESH=          4,MS=          3,          5,          10,
           0,           0,         0,NOZES=          9,         13,          25,
           0,           0,         0,MESH1=          4,MESHN=          4,LAMDA0=
   3.00000000    ,NED=         51,KN=          0,RLE=  .439999998     ,RTE=  .439
   45.7200012    ,CAMPER=          5,STABAC=  .999000013    ,CHOP=   .990000010
   2.00000000    ,SLP3=  1.00000000    ,SLP4=  1.00000000    ,MINF=   .0
 GAMMA=  1.39999962    ,TOLS=  .0            ,  .0            ,   .0            ,
    .0           ,  .0            ,  .0            ,  .0            ,OVEREL=  1.
   1.00000000    ,NOWREL=          0,NOTYET=          2,TEGARD=  2.00000000     ,
          10,ALLOUT=F,QUASI3=F,NSTRM=          1,RINF= 1.00000000      ,WAKE= .0
    .0           ,FLOCO=  999.000000    ,MINF2=  10.0000000
 &END
1                                         ELECTROSTATIC ANALOG GRID GENERATED
     NEGRID=  15 NZGRID,ODD=  49 IMAXY=  20
          SURFACE COORDINATES
          0.0130938   0.0
          0.0         0.0053293
          0.0025150   0.0139920
          0.0359481   0.0437126
          0.0738722   0.0743712
          0.1124351   0.1024950
          0.1514571   0.1289021
          0.1912974   0.1528343
          0.2313771   0.1749700
          0.2720558   0.1947904
          0.3132334   0.2126747
          0.3549501   0.2292613
          0.3971457   0.2430938
          0.4394611   0.2557086
          0.4826945   0.2662873
          0.5261875   0.2750897
          0.5700998   0.2821357
          0.6146706   0.2866666
          0.6597804   0.2899002
          0.7050898   0.2907186
          0.7512773   0.2897005
          0.7978243   0.2865070
          0.8449900   0.2816167
          0.8925548   0.2735330
          0.9410577   0.2634132
          0.9627146   0.2584230
          0.9691417   0.2518162
          0.9599799   0.2408383
          0.9466268   0.2415569
```

TABLE D.5 (Continued)

```
          0.9004390   0.2425748
          0.8548302   0.2429141
          0.8092813   0.2414372
          0.7641715   0.2390220
          0.7191616   0.2353892
          0.6748901   0.2305188
          0.6305587   C.2241917
          0.5866467   0.2171457
          0.5430139   C.2089220
          0.4997605   0.1991616
          0.4566267   0.1881836
          0.4140718   0.1765469
          0.3716765   0.1634930
          0.3293214   0.1494211
          0.2874650   0.1342515
          0.2459480   0.1177245
          0.2047305   0.1000199
          0.1636926   0.0807385
          0.1229141   0.0612974
          0.0825748   C.0401198
          0.0425948   0.0176048
          0.0130938   0.0
     NUMBER OF BODY POINTS    51         PITCH   0.5988023          CHO    0.969
   ITER COUNT FOR INTERNAL GRID POINTS=   72 ERR=      0.93749E-05
1                                 GRID OUTPUT POINTS ON BLADE SURFACE, CHORD AT ST

                                               I       X            Y

                                               0  0.46779E+00  0.13229E+00
                                               1  0.46963E+00  0.12825E+00
                                               2  0.46774E+00  0.12400E+00
                                               3  0.46393E+00  0.12059E+00
                                               4  0.45698E+00  0.11813E+00
                                               5  0.44414E+00  0.11793E+00
                                               6  0.42698E+00  0.11879E+00
                                               7  0.40705E+00  0.11922E+00
                                               8  0.38426E+00  0.11950E+00
                                               9  0.35902E+00  0.11939E+00
                                              10  0.33189E+00  0.11886E+00
                                              11  0.30367E+00  0.11774E+00
                                              12  0.27457E+00  0.11613E+00
                                              13  0.24473E+00  0.11402E+00
                                              14  0.21441E+00  0.11129E+00
                                              15  0.18384E+00  0.10789E+00
                                              16  0.15318E+00  0.10385E+00
                                              17  0.12266E+00  0.99302E-01
                                              18  0.92137E-01  0.94288E-01
                                              19  0.61648E-01  0.88725E-01
```

TABLE D.5 (Cont'd)

20	0.31281E-01	0.82462E-01
21	0.13252E-02	0.75573E-01
22	-0.28214E-01	0.68206E-01
23	-0.57339E-01	0.60491E-01
24	-0.86180E-01	0.52330E-01
25	-0.11461E+00	0.43743E-01
26	-0.14254E+00	0.34746E-01
27	-0.17005E+00	0.25421E-01
28	-0.19707E+00	0.15731E-01
29	-0.22356E+00	0.56539E-02
30	-0.24939E+00	-0.47077E-02
31	-0.27451E+00	-0.15315E-01
32	-0.29883E+00	-0.26158E-01
33	-0.32227E+00	-0.36951E-01
34	-0.34480E+00	-0.47608E-01
35	-0.36650E+00	-0.58174E-01
36	-0.38734E+00	-0.68631E-01
37	-0.40685E+00	-0.78844E-01
38	-0.42504E+00	-0.88796E-01
39	-0.44122E+00	-0.97884E-01
40	-0.45542E+00	-0.10637E+00
41	-0.46752E+00	-0.11329E+00
42	-0.47730E+00	-0.11777E+00
43	-0.48484E+00	-0.12019E+00
44	-0.49043E+00	-0.12067E+00
45	-0.49468E+00	-0.11925E+00
46	-0.49685E+00	-0.11593E+00
47	-0.49483E+00	-0.11077E+00
48	-0.48883E+00	-0.10379E+00
49	-0.47905E+00	-0.94958E-01
50	-0.46696E+00	-0.84229E-01
51	-0.45218E+00	-0.71829E-01
52	-0.43554E+00	-0.58480E-01
53	-0.41686E+00	-0.44022E-01
54	-0.39721E+00	-0.29501E-01
55	-0.37669E+00	-0.15007E-01
56	-0.35583E+00	-0.10023E-02
57	-0.33468E+00	0.12473E-01
58	-0.31339E+00	0.25319E-01
59	-0.29199E+00	0.37531E-01
60	-0.27072E+00	0.49044E-01
61	-0.24951E+00	0.59877E-01
62	-0.22830E+00	0.70028E-01
63	-0.20712E+00	0.79567E-01
64	-0.18598E+00	0.88653E-01
65	-0.16492E+00	0.97197E-01
66	-0.14400E+00	0.10509E+00
67	-0.12308E+00	0.11244E+00
68	-0.10198E+00	0.11932E+00
69	-0.80804E-01	0.12573E+00
70	-0.59691E-01	0.13173E+00
71	-0.38546E-01	0.13727E+00
72	-0.17271E-01	0.14231E+00
73	0.40976E-02	0.14690E+00
74	0.25543E-01	0.15109E+00
75	0.47074E-01	0.15483E+00
76	0.68671E-01	0.15801E+00
77	0.90393E-01	0.16068E+00
78	0.11239E+00	0.16291E+00
79	0.13459E+00	0.16470E+00
80	0.15682E+00	0.16605E+00
81	0.17914E+00	0.16693E+00
82	0.20164E+00	0.16727E+00
83	0.22428E+00	0.16709E+00
84	0.24699E+00	0.16644E+00
85	0.26976E+00	0.16530E+00
86	0.29250E+00	0.16374E+00
87	0.31517E+00	0.16172E+00
88	0.33742E+00	0.15919E+00
89	0.35926E+00	0.15617E+00
90	0.38027E+00	0.15278E+00
91	0.40063E+00	0.14895E+00
92	0.41936E+00	0.14518E+00
93	0.43656E+00	0.14176E+00
94	0.45123E+00	0.13848E+00
95	0.46149E+00	0.13541E+00
96	0.46779E+00	0.13229E+00
97	0.46963E+00	0.12825E+00
98	0.46774E+00	0.12400E+00

TABLE D.6. SAMPLE OUTPUT FROM FLOW SOLUTION RUN

```
CSCAIC VERSION 1.4.5.1          NASA DCA BLADES, FLOW SOLUTION   42.4.5.3
    CASE CONTROL INPUT ECHO

&PARAMS                             4,MS=          3,        5,       10,       15,       0,       0,       0,
NCFLOW=F,RESTAR=F,REMESH=           0,MOZES=      -9,      -13,      -25,      -49,       0,       0,       0,
       0,            0,             0,MESH1=       1,MESHN=          4,LAMDAO=  14.2700005   ,CHCRD=  5.01000023   ,S=
       0,            0,            51,KN=          0,RLE=   .0      ,RTE=   .1   ,THET1=   .0   ,THETT=
  3.00000000   ,NED=                6,STABAC=  .99400013   ,CHOP=  .95000010   ,SMOOTH=F,LECNLY=F,SLP1=  1.00000000   ,SLP2=
   .0          ,CAMBER=              ,SLP4=  1.00000000   ,MINF=  .31269974   ,BETA1=  28.1600037   ,BETA2= -12.4200001   ,
  2.00000000   ,SLP3=  1.00000000   , -.20000000768E-04,  .69999946E-04,  .60000058E-04,  -.10000034E-15,  .0
CAPPA=  1.39999992   ,TOLS=  10000.0000   ,  .0   ,OVEREL=  1.50000000   ,UNDERL=  1.00000000   ,SUPREL=
   .0          ,  .0       ,  .0   ,  10,TEGARD=  2.00000000   ,DAMP=  1.00000000   ,CII=  .35999976   ,IT=
  1.00000000   ,NCHREL=    20,NOTYET=   1,RINF=  1.00000000   ,WAKE=  .0   ,OMEGA=  .0   ,VAXIAL=
         40,ALLOUT=F,QUASI3=T,NSTRM=   ,MINF2=  10.0000000
              ,FLCCC=  959.000000
   .0
&END



 &CALCULATED FLOW PARAMETERS
 &CONST
 CIRCLN=  .369831126   ,MINF2=  .228250086   ,B2081=  .984759986   ,R2CR1=  1.00000000   ,RINF=  1.00000000   | ,RATLE=
   1.00000000
 &END
```

TABLE D.6 (Continued)

```
              RELAXATION BEGINS ON GRID OF    3 SURFACE CONTOURS INTERSECTED BY   17 RADIATING LINES
                                   SUPERSONIC RELAXATION PARAMETER, SUPREL=    0.10000E+01
 ITERATION     AVERAGE          RESIDUAL       MAX MACH        CALCULATED     RELATIVE CIRC     SUBSONIC      SUPERSONIC
   COUNT     PHI CORRECTN       AT T. E.       ON BLADE        CIRCULATION        ERROR        RELAX. FAC.   RELAX. FAC.

    40     0.131169E-01   0.889260E-02   0.313030E+00  -0.203196E-01  -0.105212E+01   0.150000E+01   0.100000E+01
    80     0.115749E-01   0.889165E-02   0.313030E+00  -0.651576E-01  -0.114714E+01   0.150000E+01   0.100000E+01
   120     0.747400E-02   0.889185E-02   0.313030E+00  -0.109995E+00  -0.128216E+01   0.150000E+01   0.100000E+01
   160     0.577920E-02   0.889184E-02   0.313030E+00  -0.154800E+00  -0.139711E+01   0.150000E+01   0.100000E+01
   200     0.471108E-02   0.889184E-02   0.313030E+00  -0.199630E+00  -0.151279E+01   0.150000E+01   0.100000E+01
   240     0.377760E-02   0.889172E-02   0.313030E+00  -0.244452E+00  -0.162707E+01   0.150000E+01   0.100000E+01
   280     0.344223E-02   0.889150E-02   0.313030E+00  -0.289275E+00  -0.174205E+01   0.150000E+01   0.100000E+01
   300     0.322454E-02   0.889149E-02   0.313030E+00  -0.311687E+00  -0.179954E+01   0.150000E+01   0.100000E+01


                           FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE    3 BY   17 MESH
RADIATING                                                            STATIC
LINE NO.     X/CX      Y/CX        X          Y         MACH      PRES COEF     PHI        XVEL       YVEL       DENSITY

    1       1.00000   0.26029    0.46563    0.12825    0.22825   -0.25555    1.79549    0.71344   -0.05291    1.02280
    2       0.93444   0.25043    0.40705    0.11922    0.22825    0.37182    1.63616    0.72002    0.07414    1.02285
    3       0.76437   0.24538    0.24473    0.11402    0.22825    0.41461   -0.67992    0.72530    0.06198    1.02278
    4       0.57256   0.21888    0.06165    0.08573    0.22753    0.46929   -0.80653    0.71730    0.14047    1.02284
    5       0.38799   0.17175   -0.11461    0.04374    0.23588    0.42828   -0.93923    0.72277    0.22641    1.02085
    6       0.22037   0.10587   -0.27459   -0.01531    0.27133    0.23670   -1.07328    0.79929    0.34281    1.01155
    7       0.08171   0.04331   -0.49685   -0.07884    0.30538    0.04462   -1.21174    0.87197    0.44070    1.00218
    8       0.0       0.0       -0.48484   -0.12019    0.31270   -2.51582   -0.65550    0.55387    0.72185    0.95595
    9       0.00607   0.02643   -0.47905   -0.09496    0.31270   -1.62470   -2.69583    0.50606    0.79545    0.95596
   10       0.11336   0.11020   -0.37669   -0.01591    0.31270   -0.06332    3.97198    0.82486    0.56148    1.00010
   11       0.24655   0.18855   -0.24552    0.05587    0.28420    0.16083   -0.77307    0.81172    0.41201    1.00785
   12       0.37901   0.24372   -0.12308    0.11244    0.27598    0.21751   -0.65663    0.83539    0.28154    1.01061
   13       0.51226   0.27983    0.03419    0.14690    0.29268    0.11854   -0.53463    0.91835    0.18635    1.00579
   14       0.64698   0.29847    0.13459    0.16470    0.28158    0.18256   -0.41129    0.89571    0.06523    1.00891
   15       0.75060   0.29911    0.26576    0.16530    0.228255636.39062   -0.29356   20.03418   -2.44723    0.50591
   16       0.92771   0.28198    0.40063    0.14895    0.228255634.02344    4.32693   20.07785   -2.59297    0.45596
   17       1.00000   0.26029    0.46563    0.12825    0.22825   11.59704    1.48380    0.97500   -0.07226    0.95988
                                                   END OF CALCULATION ON GRID 1 OF 4
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TABLE D.6 (Continued)

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            RELAXATION BEGINS ON GRID OF    5 SURFACE CONTOURS INTERSECTED BY   25 RADIATING LINES
                                SUPERSONIC RELAXATION PARAMETER, SUPREL=    0.600000E+00

 ITERATION     AVERAGE        RESIDUAL       MAX MACH       CALCULATED    RELATIVE CIRC    SUBSONIC      SUPERSONIC
   COUNT     PHI CORRECTN     AT T. E.       ON BLADE      CIRCULATION       ERROR       RELAX. FAC.    RELAX. FAC.

    40      0.210941E-02 -0.180530E-02  0.419742E+00  0.390200E+00  0.947207E-03  0.150000E+01  0.600000E+00
    55      0.113744E-02  0.195710E-03  0.410352E+00  0.389837E+00  0.139138E-04  0.150000E+01  0.600000E+00


                   FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE    5 BY   25 MESH

RADIATING                                                          STATIC
LINE NO.      X/CX      Y/CX        X          Y         MACH    PRES COEF     PHI         XVEL      YVEL      DENSITY

    1       1.00000   0.25667   0.46563    0.12825   0.20406   0.49614  -0.08157    0.65456   0.03833   1.02414
    2       0.97356   0.24596   0.44413    0.11793   0.24991   0.33310  -0.10249    0.78854   0.14505   1.01623
    3       0.88530   0.24747   0.35502    0.11559   0.24573   0.38189  -0.17239    0.78715   0.01052   1.01860
    4       0.76677   0.24191   0.24473    0.11402   0.22662   0.47420  -0.25808    0.72556   0.05994   1.02318
    5       0.64020   0.22664   0.12267    0.09930   0.22358   0.48081  -0.34508    0.70553   0.11241   1.02379
    6       0.51436   0.20274   0.00132    0.07557   0.22341   0.48956  -0.43535    0.69695   0.16360   1.02292
    7       0.39414   0.16903  -0.11461    0.04374   0.22944   0.46035  -0.52030    0.70229   0.22030   1.02241
    8       0.28115   0.12553  -0.22356    0.01565   0.22870   0.46369  -0.60856    0.68485   0.26586   1.02257
    9       0.17780   0.08535  -0.32227   -0.03695   0.24044   0.40285  -0.68443    0.69969   0.32604   1.01962
   10       0.09178   0.04190  -0.40685   -0.07884   0.21171   0.52105  -0.76353    0.60031   0.31347   1.02535
   11       0.02616   0.01618  -0.46752   -0.11329   0.21547   0.48223  -0.79844    0.65583   0.22161   1.02247
   12       0.0       0.0      -0.49469   -0.11925   0.38120  -0.81702  -0.81540    0.89487   0.81308   0.95573
   13       0.01621   0.02519  -0.47505   -0.09496   0.48649  -1.38177  -0.77073    1.00260   1.16082   0.93149
   14       0.08070   0.07801  -0.41686   -0.04402   0.41463  -0.72818  -0.65978    1.05044   0.79328   0.96414
   15       0.16592   0.13600  -0.33468    0.01247   0.37555  -0.43017  -0.53546    1.01533   0.63184   0.97988
   16       0.25424   0.18576  -0.24552    0.05987   0.35730  -0.29472  -0.42270    1.01963   0.50815   0.98535
   17       0.34197   0.22446  -0.16492    0.09720   0.34776  -0.23238  -0.31880    1.03375   0.40310   0.98661
   18       0.42919   0.25405  -0.08081    0.12573   0.33987  -0.17856  -0.22133    1.04087   0.30625   0.99125
   19       0.51724   0.27651   0.00410    0.14690   0.33186  -0.12541  -0.12733    1.03644   0.21254   0.99386
   20       0.60673   0.29029   0.09039    0.16008   0.32225  -0.06250  -0.03578    1.02309   0.11819   0.99692
   21       0.69876   0.29677   0.17914    0.16693   0.30965   0.01670   0.05444    0.99013   0.02654   1.00082
   22       0.79273   0.29509   0.26576    0.16530   0.29366   0.11413   0.14219    0.93854  -0.05505   1.00557
   23       0.88555   0.28561   0.35926    0.15617   0.27294   0.23328   0.22434    0.86612  -0.12315   1.01138
   24       0.96571   0.27067   0.43656    0.14176   0.22310   0.47305   0.29009    0.69089  -0.19073   1.02302
   25       1.00000   0.25667   0.46563    0.12825   0.20423   0.49529   0.30926    0.65511   0.03827   1.02410
                                                  END OF CALCULATION ON GRID 2 OF 4
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TABLE D.6 (Continued)

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         RELAXATION BEGINS ON GRID OF  15 SURFACE CONTOURS INTERSECTED BY  49 RADIATING LINES
                         SUPERSONIC RELAXATION PARAMETER, SUPREL=   0.50000E+00
ITERATION     AVERAGE        RESIDUAL       MAX MACH       CALCULATED     RELATIVE CIRC     SUBSONIC      SUPERSONIC
  COUNT     PHI CORRECTN    AT T. E.       ON BLADE       CIRCULATION       ERROR        RELAX. FAC.   RELAX. FAC.

   40     0.715658E-03 -0.160764E-03  0.382182E+00  0.389971E+00  0.358700E-03  0.150000E+01  0.500000E+00
   80     0.176843E-03 -0.338110E-04  0.385213E+00  0.389848E+00  0.443406E-04  0.150000E+01  0.500000E+00
  120     0.697097E-04 -0.136988E-04  0.384399E+00  0.385838E+00  0.177362E-04  0.150000E+01  0.500000E+00


                   FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE  15 BY  49 MESH
RADIATING                                                         STATIC
LINE NO.     X/CX      Y/CX       X          Y         MACH     PRES COEF     PHI       XVEL       YVEL      DENSITY

    1      1.00000   0.25760   0.46563    0.12825    0.13741    0.58914   -0.04226   0.40573    0.17519    1.02864
    2      0.99415   0.24965   0.46393    0.12059    0.25438    0.19990   -0.04935   0.72465    0.38451    1.00975
    3      0.97357   0.24685   0.44413    0.11753    0.28225    0.17222   -0.06991   0.89245    0.05963    1.00841
    4      0.93512   0.24623   0.40705    0.11922    0.24776    0.36733   -0.09584   0.79499   -0.01584    1.01755
    5      0.88532   0.24640   0.35902    0.11539    0.23182    0.45495   -0.13613   0.74132    0.00953    1.02215
    6      0.82793   0.24670   0.30368    0.11774    0.22423    0.48643   -0.17641   0.71966    0.03331    1.02367
    7      0.76681   0.24284   0.24473    0.11492    0.22194    0.50179   -0.21055   0.70769    0.05785    1.02441
    8      0.70765   0.23648   0.18285    0.10789    0.21975    0.50707   -0.26179   0.70126    0.08149    1.02467
    9      0.64025   0.22758   0.12267    0.09930    0.21987    0.50679   -0.30542   0.69802    0.10948    1.02466
   10      0.57979   0.21661   0.06165    0.08873    0.22139    0.50425   -0.34921   0.69515    0.13597    1.02453
   11      0.51444   0.20297   0.00132    0.07557    0.22195    0.49706   -0.39303   0.69388    0.16485    1.02419
   12      0.45761   0.18734  -0.05734    0.06049    0.22405    0.48739   -0.43645   0.69414    0.19073    1.02371
   13      0.39423   0.16597  -0.11461    0.04374    0.22573    0.47941   -0.47959   0.69243    0.21562    1.02333
   14      0.33674   0.15097  -0.17005    0.02542    0.22707    0.47305   -0.52208   0.68854    0.24091    1.02302
   15      0.28126   0.13048  -0.22356    0.00565    0.22832    0.46763   -0.56381   0.68322    0.26675    1.02273
   16      0.22844   0.10874  -0.27459   -0.01531    0.22584    0.45962   -0.60433   0.67768    0.29291    1.02238
   17      0.17892   0.08630  -0.32227   -0.03695    0.23184    0.45512   -0.64320   0.67199    0.31337    1.02215
   18      0.13316   0.06430  -0.36651   -0.05817    0.22967    0.46166   -0.67959   0.66037    0.32744    1.02247
   19      0.09122   0.04287  -0.40685   -0.07884    0.22572    0.47942   -0.71280   0.64001    0.34098    1.02333
   20      0.05555   0.02312  -0.44122   -0.09708    0.22115    0.50086   -0.74101   0.61751    0.35168    1.02437
   21      0.02631   0.00715  -0.46752   -0.11329    0.20281    0.57781   -0.76245   0.58437    0.28961    1.02809
   22      0.01036   0.0      -0.48484   -0.12019    0.12554    0.80755   -0.77368   0.39303    0.15126    1.03518
   23      0.00615   0.00097  -0.49468   -0.11325    0.46514   -2.69762   -0.77397   0.13725   -1.43851    0.86640
   24      0.0       0.00976  -0.49483   -0.11177    0.54719   -3.54931   -0.75000   0.51960   -0.03267    0.81972
   25      0.01630   0.02016  -0.47905   -0.09490    0.42428   -0.60051   -0.71873   0.96465    0.91771    0.96055
   26      0.04422   0.05014  -0.45218   -0.07143    0.39787   -0.59262   -0.67287   0.97617    0.80446    0.97086
   27      0.08084   0.07697  -0.41686   -0.04402    0.38330   -0.49952   -0.61727   0.97622    0.73668    0.97590
   28      0.12245   0.10505  -0.37669   -0.01591    0.37726   -0.43892   -0.55733   0.98564    0.68081    0.97645
   29      0.16605   0.13755  -0.33468    0.01247    0.37195   -0.40953   -0.49742   1.00678    0.62453    0.98034
   30      0.21031   0.16353  -0.29199    0.03753    0.36673   -0.36310   -0.43516   1.02119    0.56811    0.98218
   31      0.25435   0.18670  -0.24952    0.05987    0.36108   -0.32318   -0.38345   1.03156    0.51164    0.98415
   32      0.29932   0.20711  -0.20711    0.07556    0.35539   -0.28306   -0.33006   1.03696    0.45741    0.98612
   33      0.34207   0.22540  -0.16492    0.09729    0.35165   -0.25142   -0.27660   1.04177    0.40738    0.98773
   34      0.38545   0.24120  -0.12363    0.11244    0.34583   -0.21742   -0.22907   1.04505    0.35466    0.98935
   35      0.42928   0.25498  -0.08081    0.12573    0.34075   -0.18287   -0.18053   1.04368    0.30649    0.99104
   36      0.47310   0.26694  -0.03854    0.13726    0.33630   -0.15327   -0.13319   1.04193    0.25994    0.99250
   37      0.51731   0.27493   0.00410    0.14659    0.33216   -0.12565   -0.08652   1.03524    0.21335    0.99385
   38      0.56184   0.28515   0.04709    0.15483    0.32765   -0.09458   -0.04342   1.03384    0.16573    0.99527
   39      0.60675   0.29122   0.09039    0.16068    0.32200   -0.05963    0.00502   1.02262    0.11567    0.99708
   40      0.65261   0.29538   0.13459    0.16470    0.31548   -0.01804    0.05024   1.00620    0.07113    0.99912
   41      0.69881   0.29765   0.17914    0.16693    0.30355    0.02521    0.09480   0.98662    0.02681    1.00123
   42      0.74560   0.29707   0.22427    0.16710    0.30017    0.07666    0.13883   0.96049   -0.01680    1.00375
   43      0.79276   0.29601   0.26976    0.16530    0.29045    0.13460    0.18190   0.92859   -0.05463    1.00657
   44      0.83985   0.29225   0.31517    0.16172    0.27958    0.19768    0.22357   0.89119   -0.09082    1.00965
   45      0.88557   0.28654   0.35926    0.15617    0.26543    0.27539    0.26256   0.84177   -0.12573    1.01348
   46      0.92846   0.27905   0.40063    0.14895    0.24805    0.36369    0.29720   0.78254   -0.14620    1.01796
   47      0.96571   0.27160   0.43656    0.14176    0.22901    0.46266    0.32531   0.71753   -0.16223    1.02252
   48      0.99157   0.26501   0.46149    0.13541    0.17384    0.66371    0.34344   0.50833   -0.23369    1.03224
   49      1.00000   0.25760   0.46563    0.12825    0.13755    0.58829    0.34758   0.40616    0.17527    1.02860

                              END OF CALCULATION ON GRID 3 OF 4
```

TABLE D.6 (Continued)

```
            RELAXATION BEGINS ON GRID OF  15 SURFACE CONTOURS INTERSECTED BY  97 RADIATING LINES
                              SUPERSONIC RELAXATION PARAMETER, SUPREL=   0.50000E+00

 ITERATION    AVERAGE        RESIDUAL       MAX MACH       CALCULATED    RELATIVE CIRC     SUBSONIC      SUPERSONIC
   COUNT    PHI CORRECTN     AT T. E.       ON BLADE      CIRCULATION        ERROR       RELAX. FAC.    RELAX. FAC.

    40     0.842054E-04 -0.341288E-04  0.381786E+00  0.389843E+00  0.314971E-04  0.150000E+01  0.500000E+00
    54     0.586785E-04 -0.273761E-04  0.382888E+00  0.389340E+00  0.229348E-04  0.150060E+01  0.500000E+00


                    FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE  15 BY  97 MESH

 RADIATING                                                                STATIC
 LINE NO.      X/CX       Y/CX        X          Y         MACH     PRES COEF     PHI        XVEL       YVEL     DENSITY

     1       1.00000    0.25756    0.46563    0.12825    0.04384    0.82554   -0.03818    0.17131    0.11397    1.04004
     2       0.99474    0.25315    0.46774    0.12400    0.23020    0.39126   -0.04046    0.46586    0.57035    1.01506
     3       0.99411    0.24563    0.46293    0.12059    0.31951   -0.06779   -0.04535    0.88529    0.50842    0.99571
     4       0.98692    0.24708    0.45698    0.11813    0.32722   -0.12617   -0.05356    1.02703    0.19377    0.95392
     5       0.97362    0.24688    0.44413    0.11793    0.29199    0.17106   -0.06641    0.93477   -0.01409    1.00591
     6       0.95588    0.24777    0.42698    0.11879    0.25982    0.30647   -0.08129    0.83281   -0.03039    1.01494
     7       0.93525    0.24821    0.40705    0.11922    0.24444    0.38775   -0.09722    0.78452   -0.01326    1.01889
     8       0.91167    0.24656    0.38426    0.11950    0.23665    0.42657   -0.11477    0.76002   -0.00302    1.02077
     9       0.88556    0.24838    0.35912    0.11939    0.23133    0.45275   -0.13370    0.74296    0.00883    1.02204
    10       0.85745    0.24763    0.33189    0.11886    0.22770    0.47011   -0.15367    0.73117    0.02158    1.02288
    11       0.82629    0.24608    0.30368    0.11774    0.22540    0.48106   -0.17420    0.72335    0.03424    1.02341
    12       0.79317    0.24512    0.27457    0.11613    0.22367    0.48920   -0.19523    0.71723    0.04519    1.02380
    13       0.76730    0.24203    0.24473    0.11402    0.22209    0.49656   -0.21665    0.71134    0.05717    1.02416
    14       0.73593    0.24011    0.21441    0.11129    0.22103    0.50151   -0.23830    0.70668    0.07166    1.02440
    15       0.70431    0.23649    0.18385    0.10789    0.22177    0.50269   -0.26011    0.70425    0.08561    1.02446
    16       0.67258    0.23230    0.15218    0.10385    0.22117    0.50134   -0.28207    0.70347    0.09979    1.02439
    17       0.64101    0.22760    0.12257    0.09931    0.22125    0.50049   -0.30400    0.70241    0.10997    1.02435
    18       0.60942    0.22241    0.09214    0.09429    0.22096    0.50183   -0.32599    0.69561    0.12125    1.02442
    19       0.57787    0.21606    0.06165    0.08873    0.22165    0.50320   -0.34797    0.69493    0.13525    1.02448
    20       0.54645    0.21018    0.03128    0.08246    0.22107    0.50125   -0.36996    0.69409    0.15138    1.02439
    21       0.51545    0.20205    0.00132    0.07557    0.22224    0.49986   -0.39184    0.69444    0.16646    1.02413
    22       0.48485    0.19543   -0.02821    0.06821    0.22340    0.49145   -0.41365    0.69523    0.17877    1.02396
    23       0.45475    0.18744   -0.05734    0.06049    0.22408    0.48730   -0.43532    0.69434    0.19020    1.02371
    24       0.42472    0.17510   -0.08618    0.05233    0.22450    0.48531   -0.45692    0.69230    0.20250    1.02362
    25       0.39550    0.17011   -0.11461    0.04374    0.22591    0.48268   -0.47837    0.69012    0.21535    1.02350
    26       0.36660    0.16091   -0.14254    0.03475    0.22552    0.48052   -0.49961    0.68795    0.22736    1.02338
    27       0.33813    0.15116   -0.17005    0.02542    0.22572    0.47954   -0.52068    0.68474    0.23881    1.02334
    28       0.31017    0.14113   -0.19708    0.01573    0.22583    0.47904   -0.54150    0.68054    0.25147    1.02331
    29       0.28277    0.13070   -0.22356    0.00565    0.22610    0.47777   -0.56207    0.67655    0.26435    1.02325
    30       0.25614    0.11998   -0.24939   -0.00471    0.22641    0.47632   -0.58230    0.67250    0.27692    1.02318
    31       0.23016    0.10501   -0.27459   -0.01531    0.22696    0.47368   -0.60214    0.66883    0.29032    1.02305
    32       0.20489    0.09775   -0.29882   -0.02616    0.22777    0.46983   -0.62159    0.66648    0.30199    1.02287
    33       0.18064    0.08562   -0.32227   -0.03695    0.22901    0.46871   -0.64057    0.66376    0.30975    1.02281
    34       0.15732    0.07559   -0.34480   -0.04761    0.22720    0.47258   -0.65875    0.65805    0.31579    1.02300
    35       0.13497    0.06466   -0.36650   -0.05817    0.22544    0.48193   -0.67637    0.64929    0.32097    1.02340
    36       0.11331    0.05334   -0.38733   -0.06863    0.22296    0.49251   -0.69312    0.63752    0.32677    1.02396
    37       0.09312    0.04328   -0.40685   -0.07884    0.22034    0.50463   -0.70880    0.62430    0.33409    1.02455
    38       0.07430    0.03298   -0.42514   -0.08881    0.21735    0.51338   -0.72340    0.61096    0.33867    1.02522
    39       0.05756    0.02257   -0.44122   -0.09784    0.21451    0.53123   -0.73626    0.59658    0.34567    1.02594
    40       0.04287    0.01479   -0.45542   -0.10637    0.21228    0.54128   -0.74761    0.58512    0.34419    1.02633
    41       0.03034    0.00764   -0.46752   -0.11329    0.20314    0.57983   -0.75708    0.58060    0.29938    1.02819
    42       0.02023    0.00390   -0.47731   -0.11777    0.17516    0.68619   -0.76383    0.52431    0.20746    1.03342
    43       0.01243    0.00150   -0.48484   -0.12019    0.11493    0.86249   -0.76775    0.36020    0.08700    1.04182
    44       0.00664    0.0       -0.49043   -0.12067    0.04809    0.85274   -0.76854   -0.12434    0.09262    1.04135
    45       0.00224    0.00147   -0.49468   -0.11925    0.31438   -0.34820   -0.76699   -0.67528    0.74018    0.98292
    46       0.0        0.00491   -0.49685   -0.11593    0.51589   -2.18979   -0.76110   -0.05546    1.61058    0.85949
    47       0.00219    0.01124   -0.49463   -0.11077    0.59442   -2.39750   -0.74979    0.93968    1.60215    0.87582
    48       0.00829    0.01747   -0.48833   -0.10379    0.59153   -1.46634   -0.73407    1.09724    1.12607    0.92734
    49       0.01812    0.02660   -0.47509   -0.09496    0.43035   -0.91983   -0.71493    1.03719    0.92843    0.95461
    50       0.03093    0.03770   -0.46696   -0.08423    0.41179   -0.65585   -0.69344    0.98744    0.85264    0.96699
    51       0.04421    0.05153   -0.45218   -0.07183    0.39744   -0.58835   -0.66875    0.97669    0.80164    0.97107
    52       0.06344    0.06435   -0.43554   -0.05848    0.38850   -0.52111   -0.64215    0.97080    0.76499    0.97435
    53       0.08277    0.07631   -0.41786   -0.04402    0.38292   -0.47979   -0.61120    0.97195    0.73527    0.97643
    54       0.10395    0.09433   -0.39721   -0.02951    0.37965   -0.45172   -0.58359    0.97819    0.70693    0.97762
    55       0.12432    0.10933   -0.37669   -0.01501    0.37596   -0.42892   -0.55340    0.98597    0.67997    0.97894
    56       0.14591    0.12282   -0.35583   -0.00100    0.37310   -0.40823   -0.52342    0.99446    0.65953    0.97996
    57       0.16779    0.13776   -0.33468    0.01247    0.37020   -0.38736   -0.49273    1.00220    0.62165    0.98099
    58       0.18962    0.15106   -0.31339    0.02532    0.36718   -0.36576   -0.46451    1.00896    0.59233    0.98205
    59       0.21196    0.16369   -0.29199    0.03753    0.36417   -0.34434   -0.43581    1.01447    0.56395    0.98311
    60       0.23397    0.17560   -0.27072    0.04904    0.36146   -0.32520   -0.40784    1.01981    0.53629    0.98405
    61       0.25591    0.18690   -0.24952    0.05987    0.35966   -0.30558   -0.38050    1.02498    0.50700    0.98502
    62       0.27734    0.19731   -0.22830    0.07003    0.35514   -0.28102   -0.35372    1.02725    0.47698    0.98622
    63       0.29975    0.20718   -0.20711    0.07956    0.35172   -0.25724   -0.32754    1.02693    0.45193    0.98739
    64       0.32165    0.21658   -0.18598    0.08865    0.34960   -0.24266   -0.30183    1.02910    0.43005    0.98811
    65       0.34345    0.22542   -0.16492    0.09720    0.34807   -0.23224   -0.27653    1.03417    0.40477    0.98862
    66       0.36519    0.23359   -0.14400    0.10509    0.34634   -0.21831   -0.25179    1.03751    0.37800    0.98930
    67       0.38673    0.24120   -0.12308    0.11244    0.34351   -0.20119   -0.22736    1.03845    0.35164    0.99014
```

TABLE D.6 (Continued)

```
69      0.43647  0.25495  -0.08081  0.12573  0.33833  -0.16625  -0.17914  1.03665   0.30432  0.95186
70      0.45232  0.26115  -0.05969  0.13173  0.33675  -0.15575  -0.15550  1.03734   0.28308  0.95237
71      0.47426  0.26688  -0.03854  0.13726  0.33525  -0.14611  -0.13204  1.03845   0.25921  0.95295
72      0.49621  0.27210  -0.01727  0.14231  0.33331  -0.13288  -0.10968  1.03431   0.23472  0.95349
73      0.51832  0.27685   0.00410  0.14690  0.33127  -0.11943  -0.08549  1.03669   0.21247  0.95415
74      0.54152  0.28118   0.02555  0.15109  0.32984  -0.11096  -0.06243  1.03619   0.19117  0.95461
75      0.56279  0.28506   0.04738  0.15483  0.32843  -0.10090  -0.03544  1.03604   0.16612  0.95506
76      0.58514  0.28834   0.06867  0.15809  0.32637  -0.09552  -0.01659  1.03251   0.13945  0.95582
77      0.60761  0.29111   0.09035  0.16068  0.32301  -0.06568   0.00611  1.02584   0.11527  0.95679
78      0.63037  0.29342   0.11239  0.16291  0.31985  -0.04539   0.02983  1.01620   0.09264  0.95778
79      0.65334  0.29526   0.13459  0.16470  0.31684  -0.02626   0.05148  1.01047   0.07141  0.95872
80      0.67634  0.29666   0.15682  0.16605  0.31409  -0.00885   0.07395  1.00310   0.05029  0.95957
81      0.69944  0.29757   0.17914  0.16693  0.31106   0.01009   0.09629  0.99448   0.02709  1.00045
82      0.72272  0.29792   0.21164  0.16726  0.30722   0.03393   0.11856  0.98280   0.00383  1.00166
83      0.74613  0.29775   0.22427  0.16710  0.30275   0.06140   0.14065  0.96861  -0.01760  1.00300
84      0.76964  0.29706   0.24697  0.16644  0.29791   0.09175   0.16259  0.95283  -0.03745  1.00443
85      0.79320  0.29589   0.26976  0.16537  0.29290   0.12073   0.18496  0.93615  -0.05543  1.00590
86      0.81673  0.29427   0.29251  0.16374  0.28793   0.15003   0.20527  0.91929  -0.07252  1.00732
87      0.84019  0.29218   0.31517  0.16172  0.28267   0.18054   0.22607  0.90096  -0.09116  1.00891
88      0.86321  0.28957   0.33742  0.15919  0.27634   0.21665   0.24616  0.87863  -0.11061  1.01057
89      0.88581  0.28644   0.35926  0.15617  0.26880   0.25871   0.26543  0.85233  -0.12746  1.01262
90      0.90755  0.28294   0.38027  0.15278  0.25976   0.30774   0.28351  0.82078  -0.14311  1.01500
91      0.92851  0.27897   0.40063  0.14895  0.24895   0.36434   0.30043  0.78436  -0.15261  1.01775
92      0.94795  0.27507   0.41936  0.14518  0.23866   0.41579   0.31535  0.75230  -0.15754  1.02025
93      0.96578  0.27153   0.43656  0.14176  0.23116   0.45374   0.32855  0.72631  -0.15322  1.02239
94      0.98096  0.26814   0.45123  0.13848  0.22244   0.49405   0.33955  0.69173  -0.17992  1.02494
95      0.99158  0.26496   0.46149  0.13541  0.20247   0.57906   0.34704  0.60714  -0.23519  1.02815
96      0.99809  0.26174   0.46778  0.13229  0.13310   0.78638   0.35129  0.33378  -0.26925  1.03816
97      1.00000  0.25756   0.46963  0.12825  0.06403   0.82445   0.35166  0.17175   0.11443  1.03599

                          END OF CALCULATION ON GRID 4 OF 4
```

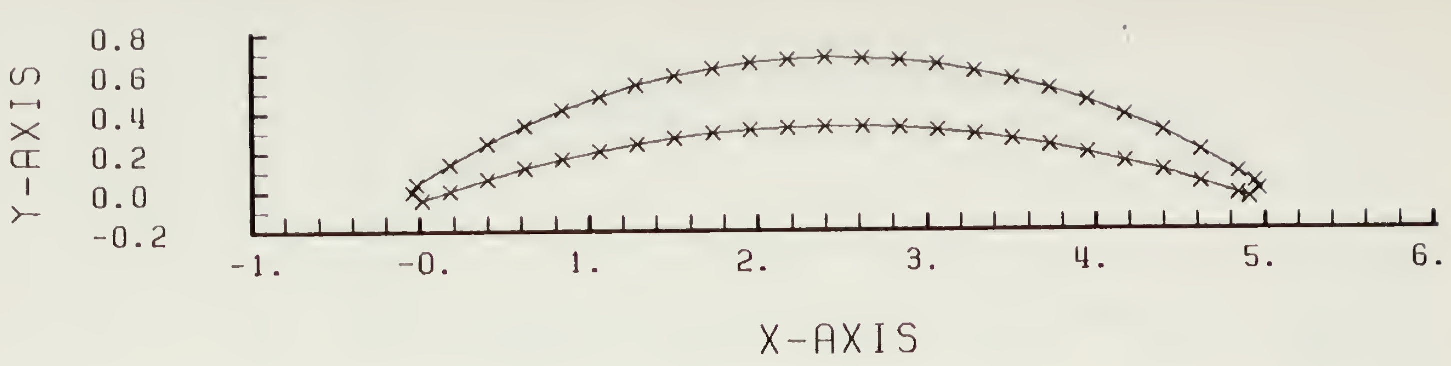

Fig. D.1. Blade Coordinates

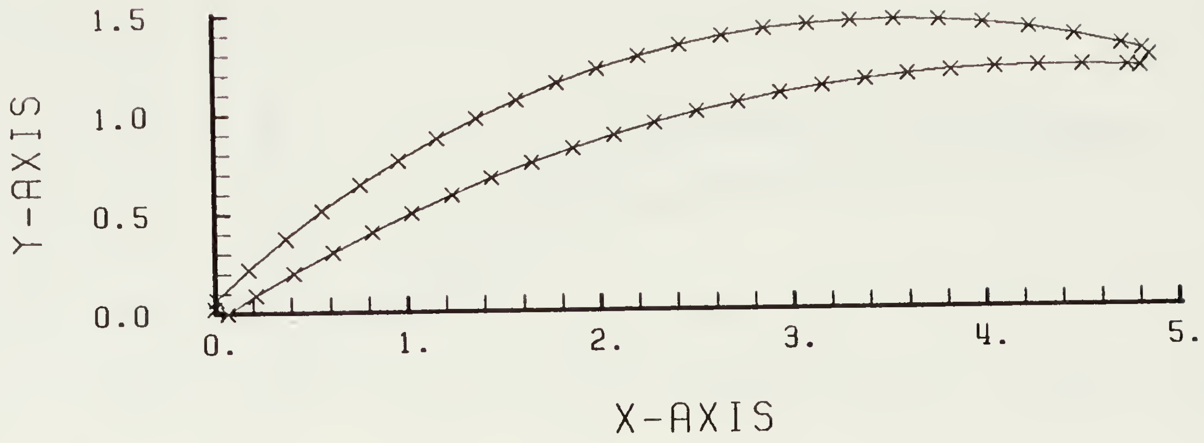

Fig. D.2. Blade Coordinates Translated and Rotated

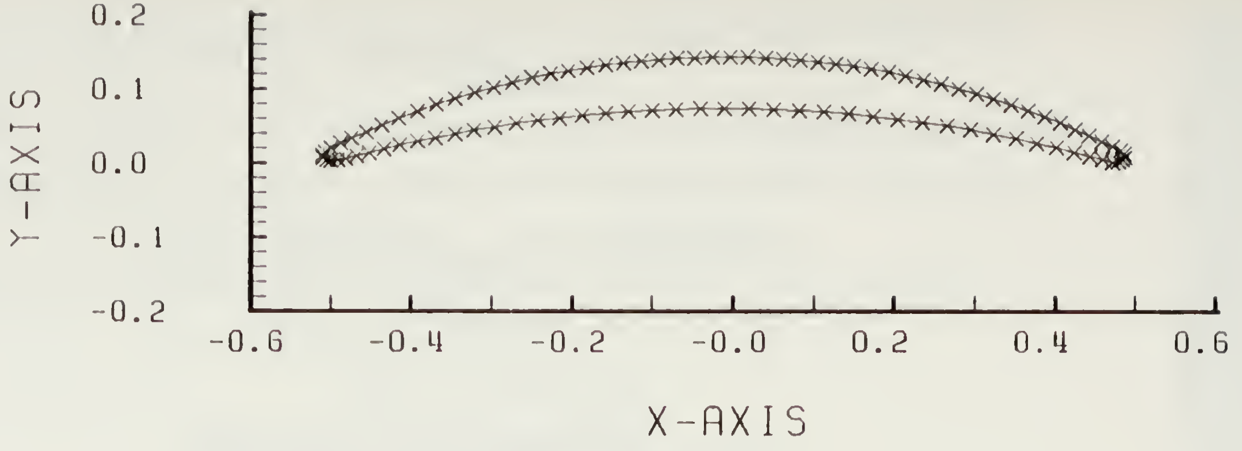

Fig. D.3. Mesh Points on Blade Surface, Horizontal Chord

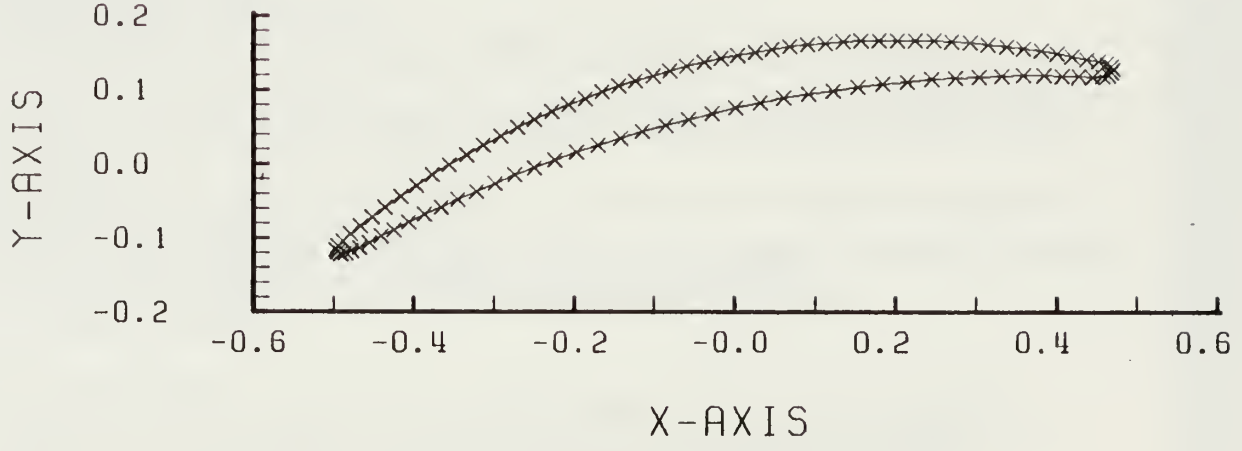

Fig. D.4. Mesh Points on Blade Surface, Chord at Stagger Angle

APPENDIX E

QSONIC PROGRAM LISTING

```
C THIS VERSION WAS COMPILED USING FORTGI. THE SAME CODE COMPILED
C  WITH FORTHX GAVE IDENTICAL RESULTS.
C                                   QSONIC
C
C      COMPUTER PROGRAM FOR CALCULATING THE FULL POTENTIAL QUASI-3D
C
C      TRANSONIC FLOW THROUGH A ROTATING TURBOMACHINERY BLADE ROW.
C
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C        ADAPTED TO THE NAVAL POSTGRADUATE SCHOOL IBM 370/3033
C                                 BY
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C
C                            QSONIC EXECUTIVE
C
C                     READS CASE CONTROL INPUT
C                     FOR EACH GRID REQUESTED, CALLS
C                         GEOMETRY SETUP
C                         STREAMCHANNEL DATA SETUP
C                         FLOW SOLVER
C                     CALLS FINAL OUTPUT GENERATOR

      LOGICAL RESTAR,NOFLOW,QUASI3,LEONLY
     1,BUG,BUG2,BUG3,SMOOTH,FINEST,ALLOUT
      INTEGER REMESH,CAMPER
      REAL MINF,LAMDAO,MINF2
      DOUBLE PRECISION CAPK,CAPKP
      COMMON/MESHES/NOZES(10),MS(10),TOLS(10),NOLD(2)
      COMMON/PARAM/RESTAR,NOZIN,BETA1,BETA2,QINF1,CI,CII,GAMMA,MINF,
     1MINF2
     1,DELTA,BETA,TOL,BUG,BUG2,BUG3,IT,GUESS,OVEREL,TIMER,NOWREL,NOTYET
     1,DAMP,SUPREL,S,WAKE,B2OB1,UNDERL,R2OR1,RINF,OMEGA,FLOCO,VAXIAL
     1,ALLOUT,KKMAX
      COMMON/QUASI/R(100,30),B(100,30)
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)
      COMMON/GEOM2/ZETA(100),ETA(100)
      COMMON/GEOM/NEWNOZ,NEWM,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK,
     1CAPKP,PI,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL
     1,FINEST,LEONLY,CAMPER

      DIMENSION TITLE(20)
      NAMELIST/PARAMS/ NOFLOW,RESTAR,REMESH,MS,NOZES,MESH1,MESHN,
     1LAMDAO,CHORD,S,NED,KN,RLE,RTE,THETL,THETT,CAMPER,STABAC,CHOP,
     1SMOOTH,LEONLY,SLP1,SLP2,SLP3,SLP4,MINF,BETA1,BETA2,GAMMA,
     1TOLS,OVEREL,UNDERL,SUPREL,NOWREL,NOTYET,TEGARD,DAMP,CII,IT,
     1ALLOUT,QUASI3,NSTRM,RINF,WAKE,OMEGA,VAXIAL,FLOCO,MINF2
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                                                                        QS000490
      DATA NSTRM,QUASI3,MESH1/1,.FALSE.,1/,REMESH/4/,TEGARD/2./         QS000500
     1,NOFLOW/.FALSE./                                                  QS000510
                                                                        QS000520
      DATA QLEVEL/'9.1'/                                                QS000530
                                                                        QS000540
      READ(5,3) TITLE                                                   QS000550
    3 FORMAT(20A4)                                                      QS000560
      WRITE(6,33) QLEVEL,TITLE                                          QS000570
   33 FORMAT(1H1,' QSONIC VERSION 1.4.',A4,2X,21A4//)                   QS000580
                                                                        QS000590
                                                                        QS000600
      READ(5,PARAMS)                                                    QS000610
      WRITE(6,2)                                                        QS000620
    2 FORMAT('0      CASE CONTROL INPUT ECHO '/)                        QS000630
      WRITE(6,PARAMS)                                                   QS000640
                                                                        QS000650
                                                                        QS000660
      BETA1=BETA1*PI/180.                                               QS000670
      LAMDA0=LAMDA0*PI/180.                                             QS000680
      BETA2=BETA2*PI/180.                                               QS000690
      MIN=MS(MESH1)                                                     QS000700
      IF(RESTAR)MESH1=REMESH                                            QS000710
      NOZIN=IABS(NOZES(MESH1))                                          QS000720
      IF(QUASI3.AND.B2OB1.EQ.1.)CALL RBIN(NSTRM,LAMDA0)                 QS000730
                                                                        QS000740
                                                                        QS000750
      DO 1 I=MESH1,MESHN                                                QS000760
      MESH=I                                                            QS000770
      NOLD(2)=NEWM                                                      QS000780
      NOLD(1)=IEXIT                                                     QS000790
      NEWNOZ=NOZES(MESH)                                                QS000800
      NEWM=MS(MESH)                                                     QS000810
      TOL=TOLS(MESH)                                                    QS000820
      REWIND 23                                                         QS000830
      REWIND 13                                                         QS000840
      CALL WRAPUP(ZETA,ETA,S)                                           QS000850
      IEXIT=2*(NEWNOZ-1)                                                QS000860
      CALL WHEEL(LAMDA0,NEWM,IEXIT,NOFLOW)                              QS000870
      IF(NOFLOW)STOP                                                    QS000880
      IF(QUASI3) CALL FILLRB(NEWM,IEXIT,RINF,LAMDA0)                    QS000890
      IF(RESTAR.OR.MESH.NE.MESH1)CALL FILPHI(NEWNOZ,NEWM,IEXIT)         QS000900
      IF(SLP1.GE.0.)SLP2=TEGARD                                         QS000910
      CALL USONIC                                                       QS000920
      MYMESH=MESH-MESH1+1                                               QS000930
      MYMAX=MESHN-MESH1+1                                               QS000940
      WRITE(6,4) MYMESH,MYMAX                                           QS000950
    4 FORMAT(1H0,40X,' END OF CALCULATION ON GRID',I2,' OF',I2)         QS000960
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1     CONTINUE

      CALL KEEPER
      STOP
      END
      BLOCK DATA

C               INITIALIZE ALL DATA IN COMMON

      LOGICAL RESTAR,LEONLY
     1,BUG,BUG2,BUG3,SMOOTH,FINEST,ALLOUT
      INTEGER CAMPER
      REAL MINF,LAMDAO
      DOUBLE PRECISION CAPK,CAPKP
      COMMON/MESHES/NOZES(10),MS(10),TOLS(10),NOLD(2)
      COMMON/PARAM/RESTAR,NOZIN,BETA1,BETA2,QINF1,CI,CII,GAMMA,MINF,EM
     1,DELTA,BETA,TOL,BUG,BUG2,BUG3,IT,GUESS,OVEREL,TIMER,NOWREL,NOTYET
     1,DAMP,SUPREL,S,WAKE,B2OB1,UNDERL,RADRAT,RADLE,OMEGA,FLOCO,VAXIAL
     1,ALLOUT,KKMAX
      COMMON/QUASI/R(100,30),B(100,30)
      COMMON/ENTIRE/   X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)
      COMMON/GEOM2/ZETA(100),ETA(100)
      COMMON/GEOM/NEWNOZ,NEWM,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK,
     1CAPKP,PI,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL
     1,FINEST,LEONLY,CAMPER

      COMMON/CALVEL/D55(55),PRIORS(14,30),INDEX(100,30),I1DEX(32),
     1FAKEU(100),FAKEV(100),ICOUNT,IDEX,AMY,AMZ

      DATA RADRAT/1./,WAKE,B2OB1/0.,1./,R,B/6000*1./
      DATA RADLE/1./,OVEREL/1.5/,TOL/.001/
     1,PI/3.14159265/,TIMER/1./
     1,OMEGA,FLOCO,VAXIAL/0.,999.,0./
     1,SUPREL/1./,CHOP/.99/,THETT,THETL/0.,0./,CAMPER/6/,EM/10./
      DATA NOTYET/2/,DAMP/1./,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH/.999,
     11.,2.,2*1.,.FALSE./,UNDERL/1./,LEONLY/.FALSE./,FINEST/.FALSE./
      DATA A/1.5/,CII/.2/,CI/1./,GUESS/10./,IT/10/,ALLOUT/.FALSE./
      DATA KKMAX/300/
      DATA DELTA,BETA,QINF1,BUG,RESTAR,GAMMA/3*1.,.FALSE.,.FALSE.,1.4/


      DATA INDEX,I1DEX/203*0,1,98*0,2,1,96*0,2,2,4,1,96*0,1,1,1,2497*0,
     1 2,8,2,8,1,1,8,3,3,3,1,1,1,8,2,8,2,8,1,1,8,3,3,3,1,1,1,8,2,8,2,8/
      END
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                                                                        QS001450
                                                                        QS001460
      SUBROUTINE WHEEL(LAMDAO,NEWM,NEW2M1,NOFLOW)                       QS001470
                                                                        QS001480
C     ROTATE X,Y COORDINATES THRU AN ANGLE LAMDAO(RADIANS)              QS001490
                                                                        QS001500
                                                                        QS001510
      LOGICAL NOFLOW                                                    QS001520
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)    QS001530
      COMMON/GEOM2/ZETA(100),ETA(100)                                   QS001540
      REAL LAMDAO                                                       QS001550
      COMPLEX H,AI                                                      QS001560
      DATA AI/(0.,1.)/                                                  QS001570
      NEW2M=NEW2M1-1                                                    QS001580
      MM3=NEWM-3                                                        QS001590
      NNOZ=(NEW2M+1)/2                                                  QS001600
      NEW2M2=NEW2M1+1                                                   QS001610
      DO 1 I=1,NEW2M2                                                   QS001620
      DO 1 J=1,NEWM                                                     QS001630
      H=CMPLX(X(I,J),Y(I,J))*CEXP(AI*LAMDAO)                            QS001640
      X(I,J)=REAL(H)                                                    QS001650
1     Y(I,J)=AIMAG(H)                                                   QS001660
      IF(.NOT.NOFLOW) RETURN                                            QS001670
      WRITE(6,10)                                                       QS001680
10    FORMAT(1H1,30X,' GRID OUTPUT POINTS ON BLADE SURFACE, CHORD ',    QS001690
     1'AT STAGGER ANGLE'//42X,'  I        X                   Y'/)      QS001700
      DO 2 I=1,NEW2M2                                                   QS001710
      I1M=I-1                                                           QS001720
2     WRITE(6,14) I1M,X(I,NEWM),Y(I,NEWM)                               QS001730
14    FORMAT(41X,I4,2E13.5)                                             QS001740
      RETURN                                                            QS001750
      END                                                               QS001760
      SUBROUTINE FILPHI(NEWNOZ,NEWM,NEW2M1)                             QS001770
                                                                        QS001780
C         BASED ON PHI ARRAY FROM PREVIOUS GRID, INTERPOLATES VALUES    QS001790
C         TO FILL THE INITIAL PHI ARRAY FOR NEXT, FINER GRID.           QS001800
                                                                        QS001810
      INTEGER OLDNOZ,OLDM                                               QS001820
      LOGICAL RESTAR                                                    QS001830
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),TOPHI(100,30)     QS001840
      COMMON/MESHES/NOZES(10),MS(10),TOLS(10),NOLD(2)                   QS001850
      COMMON/GEOM2/ ZNEW(100),ENEW(100)                                 QS001860
      COMMON/CALVEL/FAKEFI(4,6),FAKFI(4,6),RHOCON,QLIM,EXPO,ROTATN,     QS001870
     1ROTROT,IM1,IEXIT,PRIORS(14,30),INDEX(100,30),I1DEX(32),FAKEU(75)  QS001880
     1,FAKEV(75),ICOUNT,IDEX                                            QS001890
      COMMON/PARAM/ RESTAR                                              QS001900
      DIMENSION OLDE(100),OLDZ(100)                                     QS001910
                                                                        QS001920
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                                                                        QS001930
      OLDNOZ=NOLD(1)                                                    QS001940
      OLDM=NOLD(2)                                                      QS001950
      NZOLD=OLDNOZ/2+1                                                  QS001960
      INDEX(OLDNOZ-2,3)=0                                               QS001970
      INDEX(OLDNOZ-2,4)=0                                               QS001980
      INDEX(OLDNOZ-2,5)=0                                               QS001990
      INDEX(OLDNOZ-2,6)=0                                               QS002000
      INDEX(OLDNOZ-1,5)=0                                               QS002010
      INDEX(OLDNOZ-1,6)=0                                               QS002020
      INDEX(OLDNOZ,5)=0                                                 QS002030
      INDEX(OLDNOZ,6)=0                                                 QS002040
      INDEX(NZOLD-2,3)=0                                                QS002050
      INDEX(NZOLD-2,4)=0                                                QS002060
      INDEX(NZOLD-2,5)=0                                                QS002070
      INDEX(NZOLD-2,6)=0                                                QS002080
      INDEX(NZOLD-1,5)=0                                                QS002090
      INDEX(NZOLD-1,6)=0                                                QS002100
      INDEX(NZOLD,5)=0                                                  QS002110
      INDEX(NZOLD,6)=0                                                  QS002120
      INDEX(NZOLD+1,4)=0                                                QS002130
      INDEX(NZOLD+1,5)=0                                                QS002140
      INDEX(NZOLD+1,6)=0                                                QS002150
      INDEX(NZOLD+2,3)=0                                                QS002160
      INDEX(NZOLD+2,4)=0                                                QS002170
      INDEX(NZOLD+2,5)=0                                                QS002180
      DO  13 I1=1,NEW2M1                                                QS002190
      DO 13  J1=1,NEWM                                                  QS002200
13    TOPHI(I1,J1)=0.                                                   QS002210
      REWIND 18                                                         QS002220
      REWIND 8                                                          QS002230
                                                                        QS002240
                                                                        QS002250
      IF(RESTAR)GOTO10                                                  QS002260
      READ(18) OLDE,OLDZ                                                QS002270
      DO 1  I1=1,NEW2M1                                                 QS002280
      DO 2  I2=1,OLDNOZ                                                 QS002290
      IF(OLDE(I2).GT.ENEW(I1)) GOTO3                                    QS002300
2     CONTINUE                                                          QS002310
      I2=OLDNOZ                                                         QS002320
3     DO 1  I3=1,NEWM                                                   QS002330
      DO 5  I4=1,OLDM                                                   QS002340
      IF(OLDZ(I4).GT.ZNEW(I3))GOTO6                                     QS002350
5     CONTINUE                                                          QS002360
      I4=OLDM                                                           QS002370
6     FACE=(ENEW(I1)-OLDE(I2-1))/(OLDE(I2)-OLDE(I2-1))                  QS002380
      TERP3=                                                            QS002390
     1PHI(I2-1,I4)+(PHI(I2,I4)-PHI(I2-1,I4))*FACE                       QS002400
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      TERP1=
     1PHI(I2-1,I4-1)+(PHI(I2,I4-1)-PHI(I2-1,I4-1))*FACE
      BOP=(TERP3-TERP1)/(OLDZ(I4)-OLDZ(I4-1))*(ZNEW(I3)-
     1OLDZ(I4-1))+TERP1
1     TOPHI(I1,I3)=BOP


      DO 7 I1=1,NEW2M1
      DO 7 I3=1,NEWM
7     PHI(I1,I3)=TOPHI(I1,I3)


22    FORMAT(4I6,4E13.5)
4     FORMAT(1H ,8E13.5)
      WRITE(8,11) PHI
      DO  1313 I1=1,NEW2M1
      DO 1313 J1=1,NEWM
1313  TOPHI(I1,J1)=0.
      RETURN

C       IF RESTART, READ PHI FROM THE RESTART FILE
10    READ(9,11) PHI
11    FORMAT(6E13.5)
      RESTAR=.FALSE.
      REWIND 9
12    RETURN
      END
      SUBROUTINE RBIN(NSTRM,LAMDA0)

C   FOR QUASI3D CASES, READS UNIT 2 WITH DISTRIBUTIONS OF SPANWISE RADIUS
C    AND CHANNEL THICKNESS.  FORMAT IS THE SAME AS PROGRAM TSONIC.

      REAL LAMDA0
      COMMON/MERIDL/ ZMSP(50,2),THSP(50,2),RMSP(50),
     1BESP(50),RM(50),NRSP,NSP(2),RTE(2),RLE(2),STGRF,CHO,CNBL,DM
      DIMENSION DUM1(50),R(2)
      REWIND 2
      ISTRM=IABS(NSTRM)
      DO 1 I=1,ISTRM
      READ(2,3)
      READ(2,3)
      READ(2,6) A1,A2,CHO,STGRF
      READ(2,3)
3     FORMAT(1H )
      READ(2,4) NBL,NRSP,I1,I2,I3
      CNBL=FLOAT(NBL)
4     FORMAT(30X,I5,4I5)
      DO 10 J=1,2
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      READ(2,5) RI,RO,SPLNO1                                            QS002890
      ISPL1=SPLNO1                                                      QS002900
C     WRITE(6,4) I,NRSP,J,ISPL1                                         QS002910
      NSP(J)=ISPL1                                                      QS002920
      RTE(J)=RO                                                         QS002930
      RLE(J)=RI                                                         QS002940
5     FORMAT(2F10.5,20X,F10.5)                                          QS002950
6     FORMAT(8F10.6)                                                    QS002960
      READ(2,6) (ZMSP(IA,J),IA=1,ISPL1)                                 QS002970
10    READ(2,6) (THSP(IA,J),IA=1,ISPL1)                                 QS002980
                                                                        QS002990
C    READ X VALUES                                                      QS003000
                                                                        QS003010
      READ(2,6) (RM(IA),IA=1,NRSP)                                      QS003020
                                                                        QS003030
C    READ CORRESPONDING SPANWISE RADIUS  VALUES.                        QS003040
                                                                        QS003050
      READ(2,6) (RMSP(IA),IA=1,NRSP)                                    QS003060
                                                                        QS003070
C    READ STREAMCHANNEL THICKNESS VALUES.                               QS003080
                                                                        QS003090
      READ(2,6) (BESP(IA),IA=1,NRSP)                                    QS003100
                                                                        QS003110
      IF(I1.EQ.1)READ(2,6) (DUM1(IA),IA=1,NRSP)                         QS003120
      IF(I2.EQ.1)READ(2,6) (DUM1(IA),IA=1,NRSP)                         QS003130
1     READ(2,4) I4                                                      QS003140
      IF(NSTRM.LT.0) RETURN                                             QS003150
                                                                        QS003160
C     TRANSLATE ORIGIN OF X VALUES TO MIDCHORD AND NORMALIZE RADIUS AND QS003170
C     THICKNESS TO THE AERODYNAMIC CHORD.                               QS003180
                                                                        QS003190
      DO 7 I=1,NRSP                                                     QS003200
      RM(I)=(RM(I)-CHO/2.)/CHO*COS(LAMDA0)                              QS003210
      RMSP(I)=RMSP(I)/CHO*COS(LAMDA0)                                   QS003220
7     BESP(I)=BESP(I)/CHO*COS(LAMDA0)                                   QS003230
                                                                        QS003240
                                                                        QS003250
      RETURN                                                            QS003260
      END                                                               QS003270
      SUBROUTINE FILLRB(NEWM,NEW2M1,RADLE,STAG)                         QS003280
                                                                        QS003290
                                                                        QS003300
C INTERPOLATES ON THE INPUT (OR ASSUMED LINEAR) DISTRIBUTIONS OF RADIUS QS003310
C AND THICKNESS TO FILL ARRAYS OF SPANWISE POSITION AND STREAMCHANNEL   QS003320
C THICKNESS AT ALL GRID POINTS.                                         QS003330
                                                                        QS003340
C          IF RADLE=1.,  RADIUS IS ASSUMED CONSTANT                     QS003350
                                                                        QS003360
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      COMMON/QUASI/R(100,30),B(100,30)                                  QS003370
      COMMON/MERIDL/ ZMSP(50,2),THSP(50,2),RMSP(50),                    QS003380
     1BESP(50),RM(50),NRSP,NSP(2),RTE(2),RLE(2),STGRF,CHO,CNBL,DUMM     QS003390
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)    QS003400
      COMMON/PARAM/ RESTAR,NOZIN,BRM(17),USELER,BR(6),B2OB1,UNDERL,R2OR1QS003410
      NEW2M2=NEW2M1+1                                                   QS003420
      N=NRSP                                                            QS003430
      CO=COS(STAG)/2.                                                   QS003440
                                                                        QS003450
C              NOZIN=NEW2M1/2 ON THE FIRST PASS ONLY                    QS003460
                                                                        QS003470
      IF(NOZIN.EQ.NEW2M1/2)FIXR=RADLE                                   QS003480
      IF(NOZIN.EQ.NEW2M1/2)B21SAV=B2OB1                                 QS003490
      IF(RADLE.NE.1..AND.R2OR1.EQ.1.)R2OR1=RMSP(NRSP)/RMSP(1)           QS003500
      IF(B2OB1.EQ.1.)B2OB1=BESP(NRSP)/BESP(1)                           QS003510
                                                                        QS003520
                                                                        QS003530
                                                                        QS003540
      IF(B21SAV.NE.1..OR.NOZIN.NE.NEW2M1/2.OR.USELER.EQ.0..OR.RADLE.EQ.1QS003550
     *.)GOTO15                                                          QS003560
                                                                        QS003570
C          FIND L.E. OF BLADE (RM+CO=0.)                                QS003580
                                                                        QS003590
      DO 13 I5=1,NRSP                                                   QS003600
      IF(RM(I5)+CO.GT.0.)GOTO14                                         QS003610
   13 CONTINUE                                                          QS003620
      I5=NRSP                                                           QS003630
                                                                        QS003640
C    CALCULATE SPANWISE POSITION AT L.E. (FIXR)  FROM THE GIVEN RADIUS  QS003650
C    DISTRIBUTION.                                                      QS003660
   14 FIXR=                                                             QS003670
     1RMSP(I5-1)-(RMSP(I5)-RMSP(I5-1))*(CO+RM(I5-1))/(RM(I5)-RM(I5-1))  QS003680
                                                                        QS003690
                                                                        QS003700
   15 DO 1 I1=1,NEW2M2                                                  QS003710
      DO 1 I3=1,NEWM                                                    QS003720
      IF(B21SAV.NE.1.)GOTO12                                            QS003730
      DO 2 I2=1,NRSP                                                    QS003740
      IF(RM(I2).GT.X(I1,I3))GOTO3                                       QS003750
    2 CONTINUE                                                          QS003760
      I2=NRSP                                                           QS003770
    3 IF(I2.EQ.1)I2=2                                                   QS003780
      FACE=(X(I1,I3)-RM(I2-1))/(RM(I2)-RM(I2-1))                        QS003790
      TERPR=RMSP(I2-1)+(RMSP(I2)-RMSP(I2-1))*FACE                       QS003800
C     IF(RM(NRSP).LT.X(I1,I3))TERPR=RMSP(NRSP)                          QS003810
C     IF(RM(1).GT.X(I1,I3))TERPR=RMSP(1)                                QS003820
      TERPB=BESP(I2-1)+(BESP(I2)-BESP(I2-1))*FACE                       QS003830
      IF(RADLE.NE.1.)R(I1,I3)=TERPR                                     QS003840
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      B(I1,I3)=TERPB/BESP(1)                                            QS003850
      GOTO10                                                            QS003860
                                                                        QS003870
C  IF (B21SAV.NE.1), A LINEAR DISTRIBUTION OF THICKNESS IS ASSUMED OVER QS003880
C   3 CHORD LENGTHS.                                                    QS003890
                                                                        QS003900
12    B(I1,I3)=1.+(B2OB1-1.)*(X(I1,I3)+1.5)/3.                          QS003910
      IF(RADLE.NE.1.)FIXR=(1.+(R2OR1-1.)*(1.5-CO)/3.)*RADLE             QS003920
      IF(X(I1,I3).LT.-1.5)B(I1,I3)=1.                                   QS003930
      IF(X(I1,I3).GT.1.5)B(I1,I3)=B2OB1                                 QS003940
      IF(RADLE.NE.1.)R(I1,I3)=(1.+(R2OR1-1.)*(X(I1,I3)+1.5)/3.)*RADLE   QS003950
      IF(X(I1,I3).LT.-1.5)R(I1,I3)=RADLE                                QS003960
      IF(X(I1,I3).GT.1.5)R(I1,I3)=R2OR1*RADLE                           QS003970
                                                                        QS003980
                                                                        QS003990
                                                                        QS004000
C  SCALE THE TANGENTIAL COORDINATE Y (R*THETA), TO THE LOCAL RADIUS.    QS004010
                                                                        QS004020
C10   Y(I1,I3)=Y(I1,I3)*R(I1,I3)/FIXR                                   QS004030
10    CONTINUE                                                          QS004040
1     CONTINUE                                                          QS004050
      USELER=FIXR                                                       QS004060
      RETURN                                                            QS004070
4     FORMAT(2I5,6E10.4)                                                QS004080
      END                                                               QS004090
                                                                        QS004100
      SUBROUTINE USONIC                                                 QS004110
                                                                        QS004120
                                                                        QS004130
                                                                        QS004140
C                           FULL POTENTIAL FLOW SOLVER                  QS004150
C                              FOR CASCADE GEOMETRIES                   QS004160
                                                                        QS004170
C       ETA = COMPUTATIONAL COORDINATE THAT  IS CONSTANT ON LINES       QS004180
C             RADIATING FROM BLADE .                                    QS004190
C       ZETA= COMPUTATIONAL COORDINATE THAT IS CONSTANT ON LINES        QS004200
C             SURROUNDING THE BLADE.                                    QS004210
C             (THESE ARE REVERSED FROM INTERPOLATION GRID GENERATOR)    QS004220
                                                                        QS004230
                                                                        QS004240
C     DO (INPUT SPECIFICATION)                                          QS004250
C     DO (INITIALIZATION OF FIELD VARIABLES)                            QS004260
C     RELAXD= .FALSE.                                                   QS004270
C     DO UNTIL (RELAXD)                                                 QS004280
C        KK=KK+1                                                        QS004290
C        KKK=KKK+1                                                      QS004300
C        IF(KK.GT.NOWREL) OVEREL=RELSAV                                 QS004310
C        IF(KK.GT.NOTYET) SUPREL=SUPSAV                                 QS004320
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C        DO UNTIL (EXIT)                                                QS004330
C           I=I+1                                                       QS004340
C           IM1= I-1                                                    QS004350
C           IF(IM1.EQ.0) IM1=2                                          QS004360
C           DO (AXIAL LOCATION INDICATORS)                              QS004370
C           DO UNTIL (TOP)                                              QS004380
C              J=J+1                                                    QS004390
C              JM1=J-1                                                  QS004400
C              IF(JM1.EQ.0) JM1=2                                       QS004410
C              DO (VERTICAL LOCATION INDICATORS)                        QS004420
C              DO (BOUNDARY CONDITION SWITCHES)                         QS004430
C              DO (GEOMETRY ADVANCE)                                    QS004440
C              DO (FIELD GRADIENTS)                                     QS004450
C              DO (VELOCITIES AND DENSITIES)                            QS004460
C              DO (SUPERSONIC CORRECTION)                               QS004470
C              DO ( T'S,Q'S AND RESIDUALS)                              QS004480
C              DO ( DELPHI COEFFICIENTS AND TRANSPOSED TERMS)           QS004490
C           END                                                         QS004500
C           DO (FORWARD ELIMINATION)                                    QS004510
C           IF(I.NE.1)                                                  QS004520
C          1DO (BACK SUBSTITUTION)                                      QS004530
C           J=0                                                         QS004540
C        END                                                            QS004550
C        DO (UPDATE OF FIELD VARIABLES)                                 QS004560
C        DO (CONVERGENCE TESTS)                                         QS004570
C           I=0                                                         QS004580
C     END                                                               QS004590
C     DO (SURFACE FLOW CALCULATION FOR FINISHED GRID)                   QS004600
C     RETURN                                                            QS004610
C     ENTRY KEEPER                                                      QS004620
C     DO (OUTPUT OF PHI AND CALCULATION OF FINAL VELOCITY FIELD)        QS004630
C     RETURN                                                            QS004640
                                                                        QS004650
                                                                        QS004660
      LOGICAL INLET,BLADE,EXIT,BOTTOM,TOP,                              QS004670
     1  RELAXD,SETTLE,BUG,  BUG3,BUG2                                   QS004680
      LOGICAL DOSURF,SMOOTH,FINEST,RESTAR,ALLOUT                        QS004690
      REAL LAB,LAD,MINF,LENGTH,JACOB,LAMDAO                             QS004700
      REAL MACHA,MACHB,MINF2                                            QS004710
      REAL MACH(8)                                                      QS004720
      INTEGER FIRSTJ                                                    QS004730
      DOUBLE PRECISION CAPK,CAPKP                                       QS004740
      COMMON/PARAM/RESTAR,NOZIN,BETA1,BETA2,QINF1,CI,CII,GAMMA,MINF,EM  QS004750
     1,DELTA,BETA,TOL,BUG,BUG2,BUG3,IT,GUESS,OVEREL,FIXR,NOWREL,NOTYET  QS004760
     1,DAMP,SUPREL,S,WAKE,B2OB1,UNDERL,RADRAT,RADLE,OMEGA,FLOCO,VAXIAL, QS004770
     1ALLOUT,KKMAX                                                      QS004780
      COMMON/QUASI/ RADIUS(100,30),HEIGHT(100,30)                       QS004790
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)    QS004800
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      COMMON/GEOM2/ZETA(100),ETA(100)                                   QS004810
      COMMON/CROSS/ ZMACH(100,30)                                       QS004820
      COMMON/GEOM/NOZ,M,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK,       QS004830
     1CAPKP,PI                                                          QS004840
     1,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS                          QS004850
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL               QS004860
     1,FINEST                                                           QS004870
      COMMON/CALVEL/FAKEFI(4,6),FAKFI(4,6),RHOCON,QLIM,EXPO,ROTATN,     QS004880
     1ROTROT,IM1,IEXIT,PRIORS(14,30),INDEX(100,30),I1DEX(32),FAKEU(100) QS004890
     1,FAKEV(100),ICOUNT,IDEX,AMY,AMZ                                   QS004900
      COMMON/VELOUT/D(100),E(100),F( 100),DELPHI(100),TENOLF(100,30),   QS004910
     1DUMBX(100,30),DUMBY(100,30),BOPR,FADBOP,XOCX,KK                   QS004920
      DIMENSION RHOSS(8), FI1(8),FI2(3),FI3(3),FI9(8),SPAN(8),          QS004930
     1EMACH(100,30)                                                     QS004940
     2,COSX(8),COSY(8),LENGTH(8),DEDX(8),DZDX(8),DEDY(8),               QS004950
     3DZDY(8),T(8),DPHIDZ(8),DPHIDE(8),U(8),V(8),UN(8),RHO(8),          QS004960
     4RHOUL(8),ONOFF(8),DELPM1(3)                                       QS004970
     5,HITE(8)                                                          QS004980
      NAMELIST/ABSLUT/MINF,MINF2,QINF2,ABETA1,ABETA2,AQINF1,AQINF2,AMINFQS004990
     1,AEM,ROTATN                                                       QS005000
      NAMELIST/PARAMS/    IEXIT,NOZ,M,BETA1,BETA2,LAMDAO                QS005010
     1,S,CHORD,RLE,RTE,NED,KN                                           QS005020
     1,STABAC,SLP1,SLP2,SLP3,SLP4,CHOP,THETT,THETL                      QS005030
     1,QINF1,CI,CII,GAMMA,MINF,EM,DELTA,BETA,WAKE,B2OB1,RADRAT          QS005040
     1,OMEGA,FLOCO,VAXIAL                                               QS005050
     1,TOL,BUG,IT,GUESS,OVEREL,  SUPREL,NOWREL,NOTYET,DAMP,             QS005060
     1 SMOOTH,FINEST,BUG,BUG2,BUG3                                      QS005070
      NAMELIST/YTESD/ KK,AIJ,AIJM1,AIJP1, TRANSP,I,J,CIRCO              QS005080
      NAMELIST/CONST/CIRCLN,MINF2,B2OB1,R2OR1,RINF,RATLE                QS005090
      DATA AQINF1/1./,AVGFAC,TEST/1.,1./                                QS005100
                                                                        QS005110
                                                                        QS005120
      COMMON/HIBALL/ SUPERG(46,30,100)                                  QS005130
                                                                        QS005140
      XDIF(A,B,C,D)=.5*(A+B-C-D)                                        QS005150
                                                                        QS005160
                                                                        QS005170
                                                                        QS005180
                                                                        QS005190
                                                                        QS005200
                                                                        QS005210
C     DO (INPUT SPECIFICATION)                                          QS005220
                                                                        QS005230
                                                                        QS005240
C     PROCEDURE (INPUT SPECIFICATION)                                   QS005250
                                                                        QS005260
      IF(NOZ-1.NE.NOZIN) GOTO 201                                       QS005270
C     IF(NOZ-1.EQ.NOZIN) THEN                                           QS005280
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      RELSAV=OVEREL                                                     QS005290
      UNDSAV=UNDERL                                                     QS005300
      SUPSAV=SUPREL                                                     QS005310
      SHIFTM=ABS(CI)                                                    QS005320
      IF(RADRAT.EQ.1.)RADLE=1.                                          QS005330
      IF(RADRAT.EQ.1.)FIXR=1.                                           QS005340
      IF(SHIFTM.EQ.0.)SHIFTM=1.                                         QS005350
      IF(FLOCO.EQ.999..AND.OMEGA.NE.0.)                                 QS005360
     1FLOCO=VAXIAL/OMEGA/RADLE                                          QS005370
      IF(FIXR.LT.1.E-06)FIXR=1.                                         QS005380
      ROTATN=COS(BETA1+LAMDA0)/FLOCO                                    QS005390
      IF(OMEGA.EQ.0..AND.FLOCO.EQ.999.)ROTATN=0.                        QS005400
      ROTROT=ROTATN**2                                                  QS005410
      BEETA1=(BETA1+LAMDA0)                                             QS005420
      BEETA2=(BETA2+LAMDA0)                                             QS005430
                                                                        QS005440
                                                                        QS005450
C     DO (EXIT MACH NUMBER ITERATION)                                   QS005460
                                                                        QS005470
                                                                        QS005480
C     PROCEDURE (EXIT MACH NUMBER ITERATION)                            QS005490
                                                                        QS005500
      FAB=(GAMMA-1.)/2.                                                 QS005510
      ROTFAC=ROTROT*(RADRAT**2-1.)                                      QS005520
      IF(EM.NE.10.) GOTO205                                             QS005530
C     IF(EM.EQ.10.) THEN                                                QS005540
      P1OP2=1./(RADRAT-WAKE/S)                                          QS005550
      SETTLE=.FALSE.                                                    QS005560
      IF(MINF.GT.0.)EM=MINF*.8                                          QS005570
      IF(MINF.LT.0.)EM=1.0+ABS(MINF)                                    QS005580
      MINF=ABS(MINF)                                                    QS005590
      FAC1=1./(1.+FAB*MINF*MINF*(1.+ROTFAC))                            QS005600
      FAC1=FAC1**((GAMMA+1.)/4./FAB)*COS(BEETA1)/COS(BEETA2)/B2OB1      QS005610
     1*P1OP2*MINF                                                       QS005620
208   FAC2=1./(1.+FAB*EM*EM)                                            QS005630
      FAC3=FAC2**((GAMMA+1.)/4./FAB)                                    QS005640
      EFF=EM*FAC3-FAC1                                                  QS005650
      DFDM=FAC3*(1.-FAC2*EM*EM*(GAMMA+1.)/2.)                           QS005660
      DM=-EFF/DFDM                                                      QS005670
      SETTLE=ABS(DM)/EM.LT..001                                         QS005680
      EM=EM+DM                                                          QS005690
      IF(.NOT.SETTLE)GOTO208                                            QS005700
C     END                                                               QS005710
205   MINF2=EM                                                          QS005720
      MINF=ABS(MINF)                                                    QS005730
      QINF2=SQRT((1.+ROTFAC+1./FAB/MINF/MINF)/(1.+1./FAB/EM/EM))        QS005740
      AQINF2=QINF2                                                      QS005750
      ABETA2=BEETA2*180./PI                                             QS005760
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      ABETA1=BEETA1*180./PI                                             QS005770
      IF(ROTATN.EQ.0.) GOTO210                                          QS005780
C     IF(ROTATN.NE.0.) THEN                                             QS005790
      SINBET=SIN(BEETA1)+ROTATN                                         QS005800
      COSBET =COS(BEETA1)                                               QS005810
      ABETA1=ATAN2(SINBET,COSBET)*180./PI                               QS005820
      SINBET=QINF2*SIN(BEETA2)+ROTATN*RADRAT                            QS005830
      COSBET=QINF2*COS(BEETA2)                                          QS005840
      ABETA2=ATAN2(SINBET,COSBET)*180./PI                               QS005850
      AQINF1=COS(BEETA1)/COS(PI/180.*ABETA1)                            QS005860
      AQINF2=QINF2*COS(BEETA2)/COS(PI/180.*ABETA2)                      QS005870
      AMINF=MINF*COS(BEETA1)/COS(PI/180.*ABETA1)                        QS005880
      AEM=EM*COS(BEETA2)/COS(ABETA2*PI/180.)                            QS005890
      WRITE(6,779)                                                      QS005900
779   FORMAT('1ROTATION EFFECTS INCLUDED,ABSOLUTE AND RELATIVE VELOCITY'QS005910
     1,' TRIANGLES HAVE - ')                                            QS005920
      WRITE(6,ABSLUT)                                                   QS005930
      BETA1=ABETA1*PI/180.-LAMDA0                                       QS005940
      BETA2=ABETA2*PI/180.-LAMDA0                                       QS005950
C     END                                                               QS005960
210   P1OP2=1./RADRAT                                                   QS005970
      CIRCO=RADLE/FIXR*S*(AQINF1*SIN(LAMDA0+BETA1)-AQINF2*SIN(LAMDA0+   QS005980
     1BETA2)/P1OP2)                                                     QS005990
      CIRCOO=CIRCO                                                      QS006000
      IF(CIRCO.EQ.0.)CIRCOO=1.                                          QS006010
      CIRCLN=CIRCO                                                      QS006020
      R2OR1=RADRAT                                                      QS006030
      RINF=RADLE                                                        QS006040
      RATLE=FIXR                                                        QS006050
      WRITE(6,780)                                                      QS006060
780   FORMAT('1CALCULATED FLOW PARAMETERS')                             QS006070
      WRITE(6,CONST)                                                    QS006080
C       END                                                             QS006090
C     END                                                               QS006100
                                                                        QS006110
                                                                        QS006120
                                                                        QS006130
201   IF(NOZ-1.NE.NOZIN)SUPSAV=SUPSAV-CII                               QS006140
      IF(SUPSAV.LT..5)SUPSAV=.5                                         QS006150
      OVEREL=1.                                                         QS006160
      UNDERL=1.                                                         QS006170
      SUPREL=1.                                                         QS006180
      NZZ=2*NOZ-2                                                       QS006190
      KKK=0                                                             QS006200
      IEXIT=NZZ                                                         QS006210
      I67=M-14+1                                                        QS006220
      I67=MAX0(I67,1)                                                   QS006230
2     FORMAT(6E13.5)                                                    QS006240
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      KK=0                                                              QS006250
      M3=M-3                                                            QS006260
      ITIEX=IEXIT-1                                                     QS006270
      WRITE(6,777) M3,ITIEX,SUPSAV                                      QS006280
777   FORMAT(1H1,12X,                                                   QS006290
     1'RELAXATION BEGINS ON GRID OF ',I3,' SURFACE CONTOURS ',          QS006300
     1'INTERSECTED BY ',I3,' RADIATING LINES'/1H0,30X,'SUPERSONIC ',    QS006310
     1'RELAXATION ',                                                    QS006320
     1'PARAMETER, SUPREL= ',E13.5)                                      QS006330
      WRITE(6,778)                                                      QS006340
778   FORMAT(1H0,3X,'ITERATION    AVERAGE       RESIDUAL     ',         QS006350
     1' MAX MACH        ',                                              QS006360
     1' CALCULATED   RELATIVE CIRC     SUBSONIC    SUPERSONIC    '/6X,  QS006370
     1'COUNT    PHI CORRECTN    AT T. E.     ON BLADE     CIRCULATION', QS006380
     1'       ERROR     ',                                              QS006390
     1'    RELAX. FAC.  RELAX. FAC.'/)                                  QS006400
C      IF(WAKE.EQ.0.) GOTO212                                           QS006410
CC     IF(WAKE.NE.0.) THEN                                              QS006420
C      XMAX=0.                                                          QS006430
C      DO 101 I1=1,IEXIT                                                QS006440
C      IF(X(I1,M).GT.XMAX)XMAX=X(I1,M)                                  QS006450
C      IF(X(I1,M).GT.XMAX)ITE=I1                                        QS006460
C101   CONTINUE                                                         QS006470
C      X44=.95*X(ITE,M)                                                 QS006480
C      X12=(X(2,4)-X44)*SLP3                                            QS006490
C      MO2=M/2                                                          QS006500
C      DO 109 I105=1,IEXIT                                              QS006510
C      IF(ABS(X(I105,MO2)-X12-X44).LE.1.E-02) GOTO1091                  QS006520
C109   CONTINUE                                                         QS006530
C1091  CONTINUE                                                         QS006540
C      S105=RADLE/FIXR*S*RADIUS(I105,MO2)/RADLE                         QS006550
C      BDELT=WAKE/S105*SLP4                                             QS006560
C      DO 119 I=1,IEXIT                                                 QS006570
C      DO 118 J=1,M                                                     QS006580
C      IF(X(I,J).GT.X44)TERPIT=AMIN1((X(I,J)-X44)/X12,1.)               QS006590
C      IF(X(I,J).GT.X44)HEIGHT(I,J)=HEIGHT(I,J)*(1.-TERPIT*BDELT)       QS006600
C118   CONTINUE                                                         QS006610
C119   CONTINUE                                                         QS006620
C     END                                                               QS006630
C      END                                                              QS006640
                                                                        QS006650
                                                                        QS006660
                                                                        QS006670
C      DO (INITIALIZATION OF FIELD VARIABLES)                           QS006680
                                                                        QS006690
                                                                        QS006700
C      PROCEDURE (INITIALIZATION OF FIELD VARIABLES)                    QS006710
                                                                        QS006720
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212   COBB=COS(LAMDAO+BETA1)*AQINF1*RADLE                               QS006730
      COSB=COS(LAMDAO+BETA1)*AQINF1                                     QS006740
      SIBB =  SIN(LAMDAO+BETA1)*AQINF1*RADLE                            QS006750
      SINB=SIN(LAMDAO+BETA1)*AQINF1                                     QS006760
      IF(RESTAR.OR.NOZ-1.NE.NOZIN)GOTO219                               QS006770
      IEXP1=IEXIT+1                                                     QS006780
      BBLR=BEETA1+BEETA2+LAMDAO+ROTATN                                  QS006790
      DO 135 I=1,IEXP1                                                  QS006800
      DO 134  J=1,M                                                     QS006810
      PHI(I,J)=COSB*X(I,J)+SINB*Y(I,J)                                  QS006820
      IF(ROTATN.NE.0.)PHI(I,J)=PHI(I,J)*RADLE                           QS006830
      RDDDD=RADLE/HEIGHT(I,J)/RADIUS(I,J)                               QS006840
      IF(BBLR.EQ.0.)PHI(I,J)=PHI(I,J)*RDDDD                             QS006850
134   CONTINUE                                                          QS006860
135   CONTINUE                                                          QS006870
219   NOZM1=NOZ-1                                                       QS006880
      NOZP1=NOZ+1                                                       QS006890
      DO 141 I=NOZM1,NOZP1                                              QS006900
      DO 140 J=3,5                                                      QS006910
      PHI(I,J)=COSB*X(I,J)+SINB*Y(I,J)                                  QS006920
      IF(ROTATN.NE.0.)PHI(I,J)=PHI(I,J)*RADLE                           QS006930
      RDDDD=RADLE/HEIGHT(I,J)/RADIUS(I,J)                               QS006940
      IF(BBLR.EQ.0.)PHI(I,J)=PHI(I,J)*RDDDD                             QS006950
140   CONTINUE                                                          QS006960
141   CONTINUE                                                          QS006970
      DO 153  J=1,6                                                     QS006980
      DO 152 I1=1,4                                                     QS006990
      I10=IEXIT+I1-3                                                    QS007000
      IF(J.LE.5.AND.J.GT.2.AND.                                         QS007010
     1(NOZ-1.NE.NOZIN.OR.RESTAR)                                        QS007020
     1.AND.I1.NE.4)PHI(I1,J)=(COSB*X(I1,J)+SINB*Y(I1,J))                QS007030
     1                                                                  QS007040
      IF(ROTATN.NE.0.)PHI(I1,J)=PHI(I1,J)*RADLE                         QS007050
      RDDDD=RADLE/HEIGHT(I1,J)/RADIUS(I1,J)                             QS007060
      IF(BBLR.EQ.0.)PHI(I1,J)=PHI(I1,J)*RDDDD                           QS007070
      IF(J.LE.5.AND.J.GT.2.AND.                                         QS007080
     1(NOZ-1.NE.NOZIN.OR.RESTAR)                                        QS007090
     1.AND.I10.GT.IEXIT-2)PHI(I10,J)=(COSB*X(I10,J)+SINB*Y(I10,J))      QS007100
     1                                                                  QS007110
      IF(ROTATN.NE.0.)PHI(I10,J)=PHI(I10,J)*RADLE                       QS007120
      RDDDD=RADLE/HEIGHT(I10,J)/RADIUS(I10,J)                           QS007130
      IF(BBLR.EQ.0.)PHI(I10,J)=PHI(I10,J)*RDDDD                         QS007140
152   CONTINUE                                                          QS007150
153   CONTINUE                                                          QS007160
      DO 161  J=1,M                                                     QS007170
      PHI(1,J)=                                                         QS007180
     1 PHI(IEXIT-1,J)-RADLE/FIXR*S*(AQINF1*SIN(LAMDAO+BETA1)-AQINF2*SIN(QS007190
     1LAMDAO+BETA2)/P1OP2)                                              QS007200
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161    PHI(IEXIT+1,J)=PHI(3,J)+                                                  QS007210
     1    RADLE/FIXR*S*(AQINF1*SIN(LAMDAO+BETA1)-AQINF2*SIN(LAMDAO+             QS007220
     1BETA2)/P1OP2)                                                              QS007230
       I=0                                                                       QS007240
       J=0                                                                       QS007250
       RHOCON=(GAMMA-1.)/2.*MINF*MINF                                            QS007260
       EXPO= 1./(GAMMA-1.)                                                       QS007270
       QLIM=1.+1./RHOCON                                                         QS007280
       BMZ=1./MINF/MINF                                                          QS007290
       BMY=(GAMMA-2.)/2.                                                         QS007300
       AMZ=.5/BMZ                                                                QS007310
       BMX=BMY*AMZ/2.                                                            QS007320
       AMY=-BMX/BMZ                                                              QS007330
       BIGK=RADLE/FIXR*COS(BEETA1)                                               QS007340
       UOOUT=AQINF2*COS(ABETA2*PI/180.)                                          QS007350
       DPHTHO=AQINF2*SIN(ABETA2*PI/180.)*RADRAT*RADLE/FIXR                       QS007360
       UOIN=AQINF1*COS(ABETA1*PI/180.)                                           QS007370
       DPHTHI=AQINF1*SIN(ABETA1*PI/180.)*RADLE/FIXR                              QS007380
       INDEX(NOZ-2,3)=3                                                          QS007390
       INDEX(NOZ-2,4)=3                                                          QS007400
       INDEX(NOZ-2,5)=3                                                          QS007410
       INDEX(NOZ-2,6)=1                                                          QS007420
       INDEX(NOZ-1,5)=2                                                          QS007430
       INDEX(NOZ-1,6)=1                                                          QS007440
       INDEX(NOZ,5)=2                                                            QS007450
       INDEX(NOZ,6)=1                                                            QS007460
       INDEX(NOZ+1,4)=2                                                          QS007470
       INDEX(NOZ+1,5)=4                                                          QS007480
       INDEX(NOZ+1,6)=1                                                          QS007490
       INDEX(NOZ+2,3)=1                                                          QS007500
       INDEX(NOZ+2,4)=1                                                          QS007510
       INDEX(NOZ+2,5)=1                                                          QS007520
       INDEX(IEXIT-2,3)=3                                                        QS007530
       INDEX(IEXIT-2,4)=3                                                        QS007540
       INDEX(IEXIT-2,5)=3                                                        QS007550
       INDEX(IEXIT-2,6)=1                                                        QS007560
       INDEX(IEXIT-1,5)=2                                                        QS007570
       INDEX(IEXIT-1,6)=1                                                        QS007580
       INDEX(IEXIT,5)=2                                                          QS007590
       INDEX(IEXIT,6)=1                                                          QS007600
                                                                                 QS007610
                                                                                 QS007620
       IF(B2OB1*RADLE.EQ.1.)GOTO 2691                                            QS007630
C   FOR QUASI - 3D CASES, ADJUST CHANNEL AREA AT FARFIELD ELEMENTS WHERE         QS007640
C   IT DROPS BELOW SONIC THROAT AREA BASED ON THE INPUT DISTRIBUTIONS.           QS007650
                                                                                 QS007660
       DO 162 I1=1,IEXP1                                                         QS007670
       DO 162 J1=1,M                                                             QS007680
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      IF(INDEX(I1,J1).EQ.0)GOTO162                                      QS007690
      ROTFAC=ROTROT*((RADIUS(I1,J1)/RADLE)**2-1.)+1.                    QS007700
      IF(I1.LE.NOZ-3.OR.I1.GE.NOZ+3)GOTO1622                            QS007710
      ASTAR=MINF*COS(BEETA1)/(ROTFAC*MINF*MINF*FAB+1.)**((GAMMA+1.)/4.  QS007720
     1/FAB)*RADLE*((1.+MINF*MINF*SIN(BEETA1)**2)*FAB+1.)**((GAMMA+1.)/4.QS007730
     11/FAB)                                                            QS007740
      WMACH=MINF                                                        QS007750
      GOTO1623                                                          QS007760
1622  ASTAR=EM*COS(BEETA2)/(ROTFAC*EM*EM*FAB+1.)**((GAMMA+1.)/4.        QS007770
     1/FAB)*RADLE*((1.+EM*EM*SIN(BEETA2)**2)*FAB+1.)**((GAMMA+1.)/4.    QS007780
     11/FAB)*RADRAT*B20B1                                               QS007790
      WMACH=EM                                                          QS007800
1623  IF(ASTAR.LE.RADIUS(I1,J1)*HEIGHT(I1,J1))GOTO162                   QS007810
      WRITE(6,1666) I1,J1,X(I1,J1),WMACH,ASTAR                          QS007820
1666  FORMAT('OQUASI-3D CHANNEL CROSSECTION AT BOUNDARY ELEMENT I = ',I3QS007830
     1,' J = ',I3,' X = ',E13.5,' FALLS BELOW SONIC THROAT AREA'/       QS007840
     1' BASED ON MACH= ',F7.4,' AT FAR FIELD STATION.'                  QS007850
     1,' PROCEEDING WITH AREA = 1.01 * THROAT = 1.01 * ',E12.5)         QS007860
                                                                        QS007870
C     RRR=ASTAR/HEIGHT(I1,J1)                                           QS007880
C     IF(RADLE.NE.1..AND.B20B1.NE.1.)RADIUS(I1,J1)=(RRR+RADIUS(I1,J1))/2QS007890
C     IF(RADLE.NE.1..AND.B20B1.NE.1.)HEIGHT(I1,J1)=ASTAR*1.01/RADIUS(I1,QS007900
C     IF(B20B1.NE.1..AND.RADLE.EQ.1.)HEIGHT(I1,J1)=1.01*ASTAR           QS007910
C     IF(B20B1.EQ.1..AND.RADLE.NE.1.)RADIUS(I1,J1)=ASTAR*1.01           QS007920
      HEIGHT(I1,J1)=ASTAR*1.01/RADIUS(I1,J1)                            QS007930
162   CONTINUE                                                          QS007940
C     END                                                               QS007950
2691  RELAXD= .FALSE.                                                   QS007960
269   KK=KK+1                                                           QS007970
      IDEX=1                                                            QS007980
      ICOUNT=0                                                          QS007990
      KKK=KKK+1                                                         QS008000
      IF(KK.GT.NOWREL) OVEREL=RELSAV                                    QS008010
      IF(KK.GT.NOTYET) SUPREL=SUPSAV                                    QS008020
      IF(NOZ-1.NE.NOZIN)                                                QS008030
     1UNDERL=UNDSAV+FLOAT(KKK)/FLOAT(NOTYET)*(OVEREL-UNDSAV)            QS008040
272   I=I+1                                                             QS008050
      IM1= I-1                                                          QS008060
      IF(IM1.EQ.0) IM1=2                                                QS008070
                                                                        QS008080
                                                                        QS008090
C      DO (AXIAL LOCATION INDICATORS)                                   QS008100
                                                                        QS008110
                                                                        QS008120
C      PROCEDURE  (AXIAL LOCATION INDICATORS)                           QS008130
                                                                        QS008140
      INLET=.FALSE.                                                     QS008150
      EXIT  = .FALSE.                                                   QS008160
```

```
      IF(I.EQ.1) INLET =.TRUE.                                          QS008170
      IF( I.EQ. IEXIT) EXIT=.TRUE.                                      QS008180
C     END                                                               QS008190
275   J=J+1                                                             QS008200
      JM1=J-1                                                           QS008210
      IF(JM1.FQ.0) JM1=2                                                QS008220
                                                                        QS008230
                                                                        QS008240
C     DO (VERTICAL LOCATION INDICATORS)                                 QS008250
                                                                        QS008260
                                                                        QS008270
C     PROCEDURE (VERTICAL LOCATION INDICATORS)                          QS008280
                                                                        QS008290
      BOTTOM = .FALSE.                                                  QS008300
      TOP    = .FALSE.                                                  QS008310
      BLADE  = .FALSE.                                                  QS008320
      IF(J.EQ.1) BOTTOM =.TRUE.                                         QS008330
      IF(J.EQ.M) TOP =.TRUE.                                            QS008340
      BLADE = TOP                                                       QS008350
C     END                                                               QS008360
                                                                        QS008370
                                                                        QS008380
C     DO (BOUNDARY CONDITION SWITCHES)                                  QS008390
                                                                        QS008400
                                                                        QS008410
C      PROCEDURE (BOUNDARY CONDITION SWITCHES)                          QS008420
                                                                        QS008430
      DO 209 I1=1,8                                                     QS008440
209   ONOFF(I1)=1.                                                      QS008450
C     IF(INLET) THEN                                                    QS008460
C     ONOFF(3)= 0.                                                      QS008470
C     ONOFF(4)= 0.                                                      QS008480
C     ONOFF(5)= 0.                                                      QS008490
C     ONOFF(6)= 0.                                                      QS008500
C     END                                                               QS008510
C     IF(BOTTOM) THEN                                                   QS008520
C     ONOFF(5)= 0.                                                      QS008530
C     ONOFF(6)= 0                                                       QS008540
C     ONOFF(7)= 0.                                                      QS008550
C     ONOFF(8)= 0.                                                      QS008560
C     END                                                               QS008570
C     IF(TOP) THEN                                                      QS008580
C     ONOFF(1)= 0.                                                      QS008590
C     ONOFF(2)= 0.                                                      QS008600
C     ONOFF(3)= 0.                                                      QS008610
C     ONOFF(4)= 0.                                                      QS008620
C     END                                                               QS008630
      IF(.NOT.INLET.AND..NOT.BOTTOM.AND..NOT.TOP ) GOTO235              QS008640
```

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      IF(TOP)IS=1                                                       QS008650
      IF(INLET)IS=3                                                     QS008660
      IF(BOTTOM)IS=5                                                    QS008670
      IE=IS+3                                                           QS008680
      DO 2099 I1=IS,IE                                                  QS008690
2099  ONOFF(I1)=0.                                                      QS008700
C     END                                                               QS008710
                                                                        QS008720
                                                                        QS008730
                                                                        QS008740
C     DO (GEOMETRY ADVANCE)                                             QS008750
                                                                        QS008760
                                                                        QS008770
C     PROCEDURE (GEOMETRY ADVANCE)                                      QS008780
                                                                        QS008790
235   HITE(1)=XDIF(HEIGHT(I,J),HEIGHT(I+1,J),0.,0.)                     QS008800
      IF(I.EQ.IEXIT)HITE(1)=HEIGHT(I,J)                                 QS008810
      HITE(2)=XDIF(HEIGHT(I,J),HEIGHT(I,J+1),0.,0.)                     QS008820
      HITE(3)=HITE(2)                                                   QS008830
      HITE(8)=HITE(1)                                                   QS008840
      SPAN(1)=XDIF(RADIUS(I,J),RADIUS(I+1,J),0.,0.)                     QS008850
      IF(I.EQ.IEXIT)SPAN(1)=RADIUS(I,J)                                 QS008860
      SPAN(1)=SPAN(1)/FIXR                                              QS008870
      SPAN(2)=XDIF(RADIUS(I,J),RADIUS(I,J+1),0.,0.)                     QS008880
      SPAN(2)=SPAN(2)/FIXR                                              QS008890
      SPAN(3)=SPAN(2)                                                   QS008900
      SPAN(8)=SPAN(1)                                                   QS008910
      T(6) = -T(3)*ONOFF(6)                                             QS008920
      T(7) = -T(2)*ONOFF(7)                                             QS008930
                                                                        QS008940
C     CALCULATE THE METRICS ON THE FIRST ITERATION                      QS008950
C     STORE THEM FOR SUBSEQUENT ITERATIONS                              QS008960
                                                                        QS008970
      IF(KK.GT.2)GOTO237                                                QS008980
                                                                        QS008990
C     CALCULATE VELOCITIES AT UP AND DOWNSTREAM BOUNDARY ELEMENTS TO SATQS009000
C     MASS FLOW                                                         QS009010
C         INDEX(I,J)>0 POINTS TO BOUNDARY ELEMENTS AFFECTED             QS009020
                                                                        QS009030
      IF(INDEX(I,J).EQ.0.OR.KK.GT.1)GOTO2037                            QS009040
      ICOUNT=ICOUNT+1                                                   QS009050
      I1S=I1DEX(ICOUNT)                                                 QS009060
      IDIF=INDEX(I,J)+I1S-1                                             QS009070
      DO 9999 I11=I1S,IDIF                                              QS009080
      I1=I11                                                            QS009090
      IF(I1S.EQ.1.AND.I1.EQ.IDIF)I1=8                                   QS009100
      ROTATX=ROTATN*SPAN(I1)*FIXR/RADLE                                 QS009110
      BIGKH=BIGK/HITE(I1)/SPAN(I1)                                      QS009120
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      UO=UOOUT                                                          QS009130
      DPHDTH=DPHTHO                                                     QS009140
      IF(ICOUNT.GE.11.AND.ICOUNT.LE.24)UO=UOIN                          QS009150
      IF(ICOUNT.GE.11.AND.ICOUNT.LE.24)DPHDTH=DPHTHI                    QS009160
      FAKEV(IDEX)=DPHDTH/SPAN(I1)                                       QS009170
      VREL2=(FAKEV(IDEX)-ROTATX)**2                                     QS009180
      ROTATX=ROTATX*ROTATX-ROTATN*ROTATN                                QS009190
      SETTLE=.FALSE.                                                    QS009200
      YEW=UO                                                            QS009210
      IF(NOTYET.GT.KKMAX)YEW=BIGKH                                      QS009220
      JCOUNT=0                                                          QS009230
 1999 QSQAR=YEW*YEW+VREL2                                               QS009240
      IF(QSQAR.GE.QLIM)QSQAR=.99*QLIM                                   QS009250
      RHOFAC=RHOCON*(1.-QSQAR)+1.                                       QS009260
      RHOFAC=RHOFAC+ROTATX*RHOCON                                       QS009270
      IF(RHOFAC.LT.0..OR.NOTYET.GT.KKMAX)RHOFAC=1.                      QS009280
      EFF=YEW-BIGKH*RHOFAC**(-EXPO)                                     QS009290
      DFDU=1.-MINF*MINF*YEW*BIGKH*RHOFAC**(-GAMMA*EXPO)                 QS009300
      DU=-EFF/DFDU                                                      QS009310
      SETTLE=ABS(DU)/YEW.LT..001.OR.JCOUNT.GT.20                        QS009320
      YEW =YEW +DU                                                      QS009330
      JCOUNT=JCOUNT+1                                                   QS009340
      IF(.NOT.SETTLE) GOTO1999                                          QS009350
      IF(JCOUNT.GT.20)YEW=BIGKH                                         QS009360
      IF(JCOUNT.GT.20)WRITE(6,1677) I,J,I1                              QS009370
 1677 FORMAT('OCALCULATION OF VELOCITY AT BOUNDARY ELEMENT I= ',I3,     QS009380
     1' J= ','I1= ',I3,' EXCEEDS 20 ITERATIONS. PROCEEDING WITH'/       QS009390
     1 'INCOMPRESSIBLE ASSUMPTION (VELOCITY.EQ.MASS FLOW/AREA) ' )      QS009400
      FAKEU(IDEX)=YEW                                                   QS009410
 9999 IDEX=IDEX+1                                                       QS009420
      ICOUNT=ICOUNT-1                                                   QS009430
      IDEX=IDEX-INDEX(I,J)                                              QS009440
                                                                        QS009450
                                                                        QS009460
                                                                        QS009470
C     IF(KK.LE.2) THEN                                                  QS009480
 2037 IF(TOP) GOTO239                                                   QS009490
C     IF(.NOT.TOP) THEN                                                 QS009500
      XABMXA = XDIF(X(I+1,J+1),X(I,J+1),X(I,J),X(I+1,J))*.5             QS009510
      XABMXB =.5*XDIF(X(I+1,J+1),X(I+1,J),X(I,J),X(I,J+1))              QS009520
      YABMYA =.5*XDIF(Y(I+1,J+1),Y(I,J+1),Y(I,J),Y(I+1,J))              QS009530
      YABMYB =.5*XDIF(Y(I+1,J+1),Y(I+1,J),Y(I,J),Y(I,J+1))              QS009540
      XBCMXB =.5*XDIF(X(IM1,J+1),X(IM1,J),X(I,J),X(I,J+1))              QS009550
      YBCMYB =.5*XDIF(Y(IM1,J+1),Y(IM1,J),Y(I,J),Y(I,J+1))              QS009560
      LAB    = SQRT( XABMXA*XABMXA + SPAN(1)*YABMYA*SPAN(1)*YABMYA)     QS009570
      HAB    = SQRT( XABMXB*XABMXB + SPAN(2)*YABMYB*SPAN(2)*YABMYB)     QS009580
      HBC    = SQRT( XBCMXB*XBCMXB + SPAN(3)*YBCMYB*SPAN(3)*YBCMYB)     QS009590
      COSX(1)=  YABMYA*SPAN(1)/LAB                                      QS009600
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      COSX(2)=     -YABMYB*SPAN(2)/HAB                                  QS009610
      COSX(3)=      YBCMYB*SPAN(3)/HBC                                  QS009620
      COSY(1)=                -XABMXA/LAB                               QS009630
      COSY(2)=  XABMXB/HAB                                              QS009640
      COSY(3)= -XBCMXB/HBC                                              QS009650
C     END                                                               QS009660
239   IF(BOTTOM)GOTO241                                                 QS009670
C     IF(.NOT.BOTTOM) THEN                                              QS009680
      XADMXA =.5*XDIF(X(I+1,JM1),X(I,JM1),X(I,J),X(I+1,J))              QS009690
      YADMYA =.5*XDIF(Y(I+1,JM1),Y(I,JM1),Y(I,J),Y(I+1,J))              QS009700
      LAD    = SQRT(XADMXA*XADMXA + SPAN(8)*YADMYA*SPAN(8)*YADMYA)      QS009710
      COSX(8)= -YADMYA*SPAN(8)/LAD                                      QS009720
      COSY(8)=  XADMXA/LAD                                              QS009730
C     END                                                               QS009740
241   LENGTH(1) =  LAB                                                  QS009750
      LENGTH(2) =  HAB                                                  QS009760
      LENGTH(3) =  HBC                                                  QS009770
      LENGTH(8) =  LAD                                                  QS009780
      EXDIF1=X(I+1,J)-X(I,J)                                            QS009790
      EXDIF2=X(IM1,J)-X(I,J)                                            QS009800
      YDIF1=SPAN(1)*(Y(I+1,J)-Y(I,J))                                   QS009810
      YDIF2=Y(IM1,J)-Y(I,J)                                             QS009820
      SLEN=EXDIF1*EXDIF1+YDIF1*YDIF1                                    QS009830
      ZETDF1     = ZETA(J+1) - ZETA(J)                                  QS009840
      ZETDF2     = ZETA(JM1) - ZETA(J)                                  QS009850
      ETADF1     = ETA(I+1)  - ETA(I)                                   QS009860
      ETADF2 = ETA(IM1)-ETA(I)                                          QS009870
C     CELL I, POINT  A                                                  QS009880
      EK4 = 2.*YABMYA/ZETDF1                                            QS009890
      EK3 = (Y(I+1,J)-Y(I,J))/ETADF1                                    QS009900
      EK2 = 2.*XABMXA/ZETDF1                                            QS009910
      EK1 = (X(I+1,J)-X(I,J))/ETADF1                                    QS009920
      L = 1                                                             QS009930
C     DO (TRANSFORMATION MATRIX)                                        QS009940
C     PROCEDURE (TRANSFORMATION MATRIX)                                 QS009950
      JACOB=EK1*EK4-EK2*EK3                                             QS009960
      IF(JACOB.EQ.0.) GOTO243                                           QS009970
C     IF(JACOB.NE.0.) THEN                                              QS009980
      DEDX(L)= EK4/JACOB                                                QS009990
      DEDY(L)=-EK2/JACOB/SPAN(1)                                        QS010000
      DZDX(L)= -EK3/JACOB                                               QS010010
      DZDY(L)=  EK1/JACOB/SPAN(1)                                       QS010020
C     END                                                               QS010030
C     END                                                               QS010040
243   EK4 = 2.*YADMYA/ZETDF2                                            QS010050
C            CELL  IV,  POINT A                                         QS010060
      EK2 = 2.*XADMXA/ZETDF2                                            QS010070
      L=8                                                               QS010080
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C     DO (TRANSFORMATION MATRIX)                                        QS010090
      JACOB=EK1*EK4-EK2*EK3                                             QS010100
      IF(JACOB.EQ.0.)GOTO245                                            QS010110
C     IF(JACOB.NE.0.) THEN                                              QS010120
      DEDX(L)= EK4/JACOB                                                QS010130
      DEDY(L)=-EK2/JACOB/SPAN(8)                                        QS010140
      DZDX(L)= -EK3/JACOB                                               QS010150
      DZDY(L)=  EK1/JACOB/SPAN(8)                                       QS010160
C     END                                                               QS010170
C     CELL II, POINT B                                                  QS010180
245   EK4  = (Y(I,J+1)-Y(I,J))/ZETDF1                                   QS010190
      EK3  = 2.*YBCMYB/ETADF2                                           QS010200
      EK2  = (X(I,J+1)-X(I,J))/ZETDF1                                   QS010210
      EK1  = 2.*XBCMXB/ETADF2                                           QS010220
      L=3                                                               QS010230
C     DO (TRANSFORMATION MATRIX)                                        QS010240
      JACOB=EK1*EK4-EK2*EK3                                             QS010250
      IF(JACOB.EQ.0.)GOTO247                                            QS010260
C     IF(JACOB.NE.0.) THEN                                              QS010270
      DEDX(L)= EK4/JACOB                                                QS010280
      DEDY(L)=-EK2/JACOB/SPAN(3)                                        QS010290
      DZDX(L)= -EK3/JACOB                                               QS010300
      DZDY(L)=  EK1/JACOB/SPAN(3)                                       QS010310
C     END                                                               QS010320
C     CELL I, POINT B                                                   QS010330
247   EK1 =  2.*XABMXB/ETADF1                                           QS010340
      EK3 =  2.*YABMYB/ETADF1                                           QS010350
      L=2                                                               QS010360
C     DO (TRANSFORMATION MATRIX)                                        QS010370
      JACOB=EK1*EK4-EK2*EK3                                             QS010380
      IF(JACOB.EQ.0.)GOTO249                                            QS010390
C     IF(JACOB.NE.0.) THEN                                              QS010400
      DEDX(L)= EK4/JACOB                                                QS010410
      DEDY(L)=-EK2/JACOB/SPAN(2)                                        QS010420
      DZDX(L)= -EK3/JACOB                                               QS010430
      DZDY(L)=  EK1/JACOB/SPAN(2)                                       QS010440
C     END                                                               QS010450
249   T(1)=LENGTH(1)*HITE(1)*(DEDX(1)*COSX(1)+DEDY(1)*COSY(1            QS010460
     1))*ONOFF(1)                                                       QS010470
      T(2)=LENGTH(2)*HITE(2)*(DZDX(2)*COSX(2)+DZDY(2)*COSY(2            QS010480
     1))*ONOFF(2)                                                       QS010490
      T(3)=LENGTH(3)*HITE(3)*(DZDX(3)*COSX(3)+DZDY(3)*COSY(3            QS010500
     1))*ONOFF(3)                                                       QS010510
      T(8)=LENGTH(8)*HITE(8)*(DEDX(8)*COSX(8)+DEDY(8)*COSY(8            QS010520
     1))*ONOFF(8)                                                       QS010530
                                                                        QS010540
C     STORE METRICS AND GEOMETRY AT POINT I,J                           QS010550
                                                                        QS010560
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      SUPERG(1,J,I)=COSX(1)                                             QS010570
      SUPERG(2,J,I)=COSX(2)                                             QS010580
      SUPERG(3,J,I)=COSX(3)                                             QS010590
      SUPERG(4,J,I)=COSX(8)                                             QS010600
      SUPERG(5,J,I)=COSY(1)                                             QS010610
      SUPERG(6,J,I)=COSY(2)                                             QS010620
      SUPERG(7,J,I)=COSY(3)                                             QS010630
      SUPERG(8,J,I)=COSY(8)                                             QS010640
      SUPERG(9,J,I)=LENGTH(1)                                           QS010650
      SUPERG(10,J,I)=LENGTH(2)                                          QS010660
      SUPERG(11,J,I)=LENGTH(3)                                          QS010670
      SUPERG(12,J,I)=LENGTH(8)                                          QS010680
      SUPERG(13,J,I)=EXDIF1                                             QS010690
      SUPERG(14,J,I)=EXDIF2                                             QS010700
      SUPERG(15,J,I)=YDIF1                                              QS010710
      SUPERG(16,J,I)=YDIF2                                              QS010720
      SUPERG(17,J,I)=SLEN                                               QS010730
      SUPERG(18,J,I)=SLEN2                                              QS010740
      SUPERG(19,J,I)=ZETDF1                                             QS010750
      SUPERG(20,J,I)=ZETDF2                                             QS010760
      SUPERG(21,J,I)=ETADF1                                             QS010770
      SUPERG(22,J,I)=ETADF2                                             QS010780
      SUPERG(23,J,I)=DEDX(1)                                            QS010790
      SUPERG(24,J,I)=DEDX(2)                                            QS010800
      SUPERG(25,J,I)=DEDX(3)                                            QS010810
      SUPERG(26,J,I)=DEDX(8)                                            QS010820
      SUPERG(27,J,I)=DEDY(1)                                            QS010830
      SUPERG(28,J,I)=DEDY(2)                                            QS010840
      SUPERG(29,J,I)=DEDY(3)                                            QS010850
      SUPERG(30,J,I)=DEDY(8)                                            QS010860
      SUPERG(31,J,I)=DZDX(1)                                            QS010870
      SUPERG(32,J,I)=DZDX(2)                                            QS010880
      SUPERG(33,J,I)=DZDX(3)                                            QS010890
      SUPERG(34,J,I)=DZDX(8)                                            QS010900
      SUPERG(35,J,I)=DZDY(1)                                            QS010910
      SUPERG(36,J,I)=DZDY(2)                                            QS010920
      SUPERG(37,J,I)=DZDY(3)                                            QS010930
      SUPERG(38,J,I)=DZDY(8)                                            QS010940
      SUPERG(39,J,I)=T(1)                                               QS010950
      SUPERG(40,J,I)=T(2)                                               QS010960
      SUPERG(41,J,I)=T(3)                                               QS010970
      SUPERG(42,J,I)=T(8)                                               QS010980
C       SINCE( KK.LE.2)                                                 QS010990
      GOTO 238                                                          QS011000
                                                                        QS011010
C     ELSE                                                              QS011020
                                                                        QS011030
C   IF ITERATION COUNT EXCEEDS 2, OBTAIN METRICS, ETC. FROM STORAGE     QS011040
```

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                                                                        QSO11050
  237 COSX(1)=SUPERG(1,J,I)                                             QSO11060
      COSX(2)=SUPERG(2,J,I)                                             QSO11070
      COSX(3)=SUPERG(3,J,I)                                             QSO11080
      COSX(8)=SUPERG(4,J,I)                                             QSO11090
      COSY(1)=SUPERG(5,J,I)                                             QSO11100
      COSY(2)=SUPERG(6,J,I)                                             QSO11110
      COSY(3)=SUPERG(7,J,I)                                             QSO11120
      COSY(8)=SUPERG(8,J,I)                                             QSO11130
      LENGTH(1)=SUPERG(9,J,I)                                           QSO11140
      LENGTH(2)=SUPERG(10,J,I)                                          QSO11150
      LENGTH(3)=SUPERG(11,J,I)                                          QSO11160
      LENGTH(8)=SUPERG(12,J,I)                                          QSO11170
      EXDIF1=SUPERG(13,J,I)                                             QSO11180
      EXDIF2=SUPERG(14,J,I)                                             QSO11190
      YDIF1=SUPERG(15,J,I)                                              QSO11200
      YDIF2=SUPERG(16,J,I)                                              QSO11210
      SLEN=SUPERG(17,J,I)                                               QSO11220
      SLEN2=SUPERG(18,J,I)                                              QSO11230
      ZETDF1=SUPERG(19,J,I)                                             QSO11240
      ZETDF2=SUPERG(20,J,I)                                             QSO11250
      ETADF1=SUPERG(21,J,I)                                             QSO11260
      ETADF2=SUPERG(22,J,I)                                             QSO11270
      DEDX(1)=SUPERG(23,J,I)                                            QSO11280
      DEDX(2)=SUPERG(24,J,I)                                            QSO11290
      DEDX(3)=SUPERG(25,J,I)                                            QSO11300
      DEDX(8)=SUPERG(26,J,I)                                            QSO11310
      DEDY(1)=SUPERG(27,J,I)                                            QSO11320
      DEDY(2)=SUPERG(28,J,I)                                            QSO11330
      DEDY(3)=SUPERG(29,J,I)                                            QSO11340
      DEDY(8)=SUPERG(30,J,I)                                            QSO11350
      DZDX(1)=SUPERG(31,J,I)                                            QSO11360
      DZDX(2)=SUPERG(32,J,I)                                            QSO11370
      DZDX(3)=SUPERG(33,J,I)                                            QSO11380
      DZDX(8)=SUPERG(34,J,I)                                            QSO11390
      DZDY(1)=SUPERG(35,J,I)                                            QSO11400
      DZDY(2)=SUPERG(36,J,I)                                            QSO11410
      DZDY(3)=SUPERG(37,J,I)                                            QSO11420
      DZDY(8)=SUPERG(38,J,I)                                            QSO11430
      T(1)=SUPERG(39,J,I)                                               QSO11440
      T(2)=SUPERG(40,J,I)                                               QSO11450
      T(3)=SUPERG(41,J,I)                                               QSO11460
      T(8)=SUPERG(42,J,I)                                               QSO11470
C     END                                                               QSO11480
C     CELL  II,  POINT  C                                               QSO11490
  238 T(5) =  PRIORS(1,J)*ONOFF(5)                                      QSO11500
      T(4) =  PRIORS(2,J)*ONOFF(4)                                      QSO11510
      PRIORS(1,J) = - T(8)                                              QSO11520
```

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      PRIORS(2,J) = - T(1)                                              QS011530
C     END                                                               QS011540
                                                                        QS011550
                                                                        QS011560
                                                                        QS011570
C     DO (FIELD GRADIENTS)                                              QS011580
                                                                        QS011590
                                                                        QS011600
C     PROCEDURE (FIELD GRADIENTS)                                       QS011610
                                                                        QS011620
      DO 438 I1=1,3                                                     QS011630
      FI1(I1)=PHI(I+1,J)                                                QS011640
      FI2(I1)=PHI(I+1,J+1)                                              QS011650
      FI3(I1)=PHI(I  ,J+1)                                              QS011660
438   FI9(I1)=PHI(I  ,J  )                                              QS011670
      FI4    =PHI(IM1,J+1)                                              QS011680
      FI5    =PHI(IM1,J  )                                              QS011690
      FI6    =PHI(IM1,JM1)                                              QS011700
      FI7    =PHI(I  ,JM1)                                              QS011710
      FI8    =PHI(I+1,JM1)                                              QS011720
      FI1(8)=PHI(I+1,J)                                                 QS011730
      FI9(8)=PHI(I  ,J)                                                 QS011740
      I10=I-IEXIT+3                                                     QS011750
                                                                        QS011760
C     CELL I , POINT A                                                  QS011770
251   DPHIDZ(1)= XDIF(FI3(1),FI2(1),FI9(1),FI1(1))/ZETDF1               QS011780
      DPHIDE(1) =   (FI1(1)-FI9(1))/ETADF1                              QS011790
C     CELL I, POINT B                                                   QS011800
      DPHIDE(2)=XDIF(FI1(2),FI2(2),FI9(2),FI3(2)) /ETADF1               QS011810
      DPHIDZ(2)=(FI3(2)-FI9(2))/ZETDF1                                  QS011820
C     CELL II, POINT B                                                  QS011830
      DPHIDE(3)=XDIF(FI5,FI4,FI9(3),FI3(3)) /ETADF2                     QS011840
      DPHIDZ(3)=(FI3(3)-FI9(3))/ZETDF1                                  QS011850
C     CELL IV, POINT A                                                  QS011860
      DPHIDE(8) =   (FI1(8)-FI9(8))/ETADF1                              QS011870
      DPHIDZ(8) =XDIF(FI7,FI8,FI9(8),FI1(8))/ZETDF2                     QS011880
C     END                                                               QS011890
                                                                        QS011900
                                                                        QS011910
                                                                        QS011920
C     DO (VELOCITIES AND DENSITIES)                                     QS011930
                                                                        QS011940
                                                                        QS011950
C     PROCEDURE (VELOCITIES AND DENSITIES)                              QS011960
                                                                        QS011970
      U(6) = U(3)                                                       QS011980
      V(6) = V(3)                                                       QS011990
      U(7) = U(2)                                                       QS012000
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      V(7) = V(2)                                                       QS012010
      DO 541 I1 =1,8                                                    QS012020
      IF(I1.GE.4.AND.I1.NE.8) GOTO 541                                  QS012030
C     IF(I1.LT.4.OR.I1.EQ.8) THEN                                       QS012040
      U(I1)=DPHIDE(I1)*DEDX(I1)+ DPHIDZ(I1)*DZDX(I1)                    QS012050
      V(I1)=DPHIDE(I1)*DEDY(I1)+ DPHIDZ(I1)*DZDY(I1)                    QS012060
      IF(INDEX(I,J).EQ.0)GOTO5411                                       QS012070
      ICOUNT=ICOUNT+1                                                   QS012080
      I1S=I1DEX(ICOUNT)                                                 QS012090
      IF(I1.LE.I1S)I1P=I1S                                              QS012100
      IDIF=INDEX(I,J)+I1S-1                                             QS012110
      IF(I1S.EQ.1.AND.I1P.EQ.IDIF)I1P=8                                 QS012120
      IF(I1.NE.I1P)GOTO5410                                             QS012130
      IF(I1P.GT.IDIF.AND.I1P.NE.8)GOTO5410                              QS012140
      V(I1)=FAKEV(IDEX)                                                 QS012150
      U(I1)=FAKEU(IDEX)                                                 QS012160
      IDEX=IDEX+1                                                       QS012170
      I1P=I1P+1                                                         QS012180
5410  IF(I1.NE.8)ICOUNT=ICOUNT-1                                        QS012190
5411  V(I1)=V(I1)-SPAN(I1)*FIXR/RADLE*ROTATN                            QS012200
      UN(I1)=U(I1)*COSX(I1)+V(I1)*COSY(I1)                              QS012210
C     END                                                               QS012220
541   CONTINUE                                                          QS012230
      IF(.NOT.TOP) GOTO 2003                                            QS012240
      U8=SQRT(U(8)*U(8)+V(8)*V(8))*ABS(EXDIF1)/SQRT(SLEN)               QS012250
      IF(KK.GT.7.OR.ABS(FLOCO).GT..01)U(8)=SIGN(U8,U(8))                QS012260
      V(8)=U(8)*YDIF1/EXDIF1                                            QS012270
      UN(8)=U(8)*COSX(8)+V(8)*COSY(8)                                   QS012280
C     END                                                               QS012290
2003  U(4)  =  PRIORS(3,J)                                              QS012300
      U(5)  =  PRIORS(4,J)                                              QS012310
      V(4)  =  PRIORS(5,J)                                              QS012320
      V(5)  =  PRIORS(6,J)                                              QS012330
      PRIORS(3,J)=U(1)                                                  QS012340
      PRIORS(4,J)=U(8)                                                  QS012350
      PRIORS(5,J)=V(1)                                                  QS012360
      PRIORS(6,J)=V(8)                                                  QS012370
      RHO(7)=RHO(2)                                                     QS012380
      RHO(6)=RHO(3)                                                     QS012390
      RHO(4)=PRIORS(7,J)                                                QS012400
      RHO(5)=PRIORS(8,J)                                                QS012410
      ONSUM=0.                                                          QS012420
      DO 595 I1=1,8                                                     QS012430
                                                                        QS012440
C     IF(KK.LE.2.OR.MOD(KK,2).EQ.0) THEN                                QS012450
      IF(I1.GE.4.AND.I1.NE.8) GOTO 2005                                 QS012460
C     IF(I1.LT.4.OR.I1.EQ.8) THEN                                       QS012470
      RHOFAC=1.                                                         QS012480
```

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      RHO(I1)=1.                                                        QS012490
       IF((I.EQ.2.OR.I.EQ.IEXIT).AND.J.LE.4.AND.ROTATN.NE.0.            QS012500
     1.OR.KK.LE.NOTYET) GOTO 2005                                       QS012510
      QSQAR=U(I1)*U(I1)+(V(I1)*V(I1))                                   QS012520
      IF(QSQAR.GE.QLIM)QSQAR=.99*QLIM                                   QS012530
      RHOFAC=RHOCON*(1.-QSQAR)*ONOFF(I1)+1.                             QS012540
      RHO(I1)=1.-AMZ*(QSQAR-1.)+AMY*(QSQAR-1.)*(QSQAR-1.)               QS012550
      IF(QSQAR.LT..65.OR.QSQAR.GT.1.44)RHO(I1)=RHOFAC**EXPO             QS012560
                                                                        QS012570
C CORRECT DENSITY FOR ROTATION                                          QS012580
                                                                        QS012590
      ROTATX=SPAN(I1)*FIXR/RADLE                                        QS012600
       IF(ROTROT.NE.0..AND.J.GT.3)                                      QS012610
     1RHO(I1)=(RHO(I1)**(1./EXPO)+RHOCON*ROTROT*((ROTATX)               QS012620
     1**2-1.)*ONOFF(I1))**EXPO                                          QS012630
2005  QSQAR=U(I1)*U(I1)+V(I1)*V(I1)                                     QS012640
      IF(I.GT.1)                                                        QS012650
     1MACH(I1)=MINF*SQRT(QSQAR)/RHO(I1)**(1./EXPO)                      QS012660
C    1MACH(I1)=MINF*SQRT(QSQAR/RHO(I1)**(1./EXPO))                      QS012670
      IF(MACH(I1).GT.2.)MACH(I1)=2.                                     QS012680
595   CONTINUE                                                          QS012690
      PRIORS(7,J)=RHO(1)                                                QS012700
      PRIORS(8,J)=RHO(8)                                                QS012710
C     END                                                               QS012720
                                                                        QS012730
                                                                        QS012740
                                                                        QS012750
C     DO (SUPERSONIC CORRECTION)                                        QS012760
                                                                        QS012770
                                                                        QS012780
C     PROCEDURE (SUPERSONIC CORRECTION)                                 QS012790
                                                                        QS012800
      ONSUM=0.                                                          QS012810
      ROSUM=RHO(4)+RHO(5)+RHO(6)+RHO(7)                                 QS012820
      EMACH(I,J)=0.                                                     QS012830
      XVELIJ=0.                                                         QS012840
      DO 608 I3=1,8                                                     QS012850
      RHOSS(I3)=0.                                                      QS012860
608   ONSUM=ONSUM+ONOFF(I3)                                             QS012870
      YVELIJ=0.                                                         QS012880
      SMALLA=0.                                                         QS012890
      SMALLB=0.                                                         QS012900
      ZETDF1=ZETA(J+1)-ZETA(J)                                          QS012910
      IF(J.EQ.M)ZETDF1=ZETA(J)-ZETA(J-1)                                QS012920
      EMACH(I,J)=(ONOFF(1)*MACH(1)+ONOFF(8)*MACH(8))/(ONOFF(1)+ONOFF(8) QS012930
     1)                                                                 QS012940
      EMACH(IEXIT+1,J)=EMACH(3,J)                                       QS012950
      EMACH(1,J)=EMACH(IEXIT-1,J)                                       QS012960
```

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C      IF(KK.LE.2.OR.MOD(KK,IT).EQ.0.OR.MOD(KK,IT).GE.IT/2) THEN           QS012970
C        STORE DENSITIES FROM SURFACE OF ELEMENT IN DUMMY ARRAYS             QS012980
                                                                             QS012990
       DUMBX(I,J)=(ONOFF(1)*RHO(1)+ONOFF(8)*RHO(8))/(ONOFF(1)+ONOFF(8)      QS013000
      1)                                                                     QS013010
       IF(.NOT.TOP)DUMBY(I,J)=(ONOFF(2)*RHO(2)+ONOFF(3)*RHO(3))/            QS013020
      1(ONOFF(2)+ONOFF(3))                                                   QS013030
       IF(.NOT.TOP)ZMACH(I,J)=(ONOFF(2)*MACH(2)+ONOFF(3)*MACH(3))/          QS013040
      1(ONOFF(2)+ONOFF(3))                                                   QS013050
       IF(TOP)DUMBY(I,J)=2.*DUMBY(I,J-1)-DUMBY(I,J-2)                        QS013060
       IF(TOP)ZMACH(I,J)=2.*ZMACH(I,J-1)-ZMACH(I,J-2)                        QS013070
       DUMBX(IEXIT+1,J)=DUMBX(3,J)                                           QS013080
       ZMACH(1,J)=ZMACH(IEXIT-1,J)                                           QS013090
       DUMBY(I,M+1)=2.*DUMBY(I,1)-DUMBY(I,2)                                 QS013100
       ZMACH(I,M+1)=2.*ZMACH(I,1)-ZMACH(I,2)                                 QS013110
                                                                             QS013120
C     CALCULATE DENSITY CORRECTION TERMS,   MU*DRHODS*DS                     QS013130
                                                                             QS013140
C      IF(J.GT.5.OR.I.LT.NOZ-1.OR.I.GT.NOZ+1) THEN                           QS013150
       IF(J.LE.5.AND.I.GE.NOZ-1.AND.I.LE.NOZ+1) GOTO20001                    QS013160
       DO 694 I1=2,8,6                                                       QS013170
       IF(TOP.AND.I1.NE.8) GOTO 694                                          QS013180
C      IF(.NOT.TOP.OR.I1.EQ.8) THEN                                          QS013190
       I1P1=I1+1                                                             QS013200
       IF(I1.EQ.8)I1P1=1                                                     QS013210
       ONSUM=ONOFF(I1)+ONOFF(I1P1)                                           QS013220
       XVELIJ=U(I1)*ONOFF(I1)/ONSUM                                          QS013230
       XVELIJ=XVELIJ+U(I1P1)*ONOFF(I1P1)/ONSUM                               QS013240
       YVELIJ=V(I1)*ONOFF(I1)/ONSUM                                          QS013250
       YVELIJ=YVELIJ+V(I1P1)*ONOFF(I1P1)/ONSUM                               QS013260
       SMALLA=(U(I1)*DZDX(I1)+V(I1)*DZDY(I1))*ONOFF(I1)/ONSUM                QS013270
       SMALLA=SMALLA+(U(I1P1)*DZDX(I1P1)+V(I1P1)*DZDY(I1P1))                 QS013280
      1*ONOFF(I1P1)/ONSUM                                                    QS013290
       SMALLB=(U(I1)*DEDX(I1)+V(I1)*DEDY(I1))*ONOFF(I1)                      QS013300
      1/ONSUM                                                                QS013310
       SMALLB=SMALLB+(U(I1P1)*DEDX(I1P1)+V(I1P1)*DEDY(I1P1))                 QS013320
      1*ONOFF(I1P1)/ONSUM                                                    QS013330
       IF(KK.LE.NOTYET) GOTO694                                              QS013340
C      IF(KK.GT.NOTYET) THEN                                                 QS013350
       IF(BLADE)SMALLA=0.                                                    QS013360
       SIGNOA=SIGN(1.,SMALLA)                                                QS013370
       IF(SMALLA.EQ.0.)SIGNOA=1.                                             QS013380
       FLOWAT=AMAX1(0.,SIGNOA)                                               QS013390
       SIGNOB=SIGN(1.,SMALLB)                                                QS013400
       FLOWBY=AMAX1(0.,SIGNOB)                                               QS013410
       QUE=SQRT(XVELIJ**2+YVELIJ**2)                                         QS013420
C         SLP2=TEGARD                                                        QS013430
       IF(ABS(SMALLB)/QUE.GT.SLP2)QUE=SQRT(SMALLA**2+SMALLB**2)              QS013440
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      MYJ=J-IFIX(SIGNOA)                                                QS013450
      MYI=I-IFIX(SIGNOB)                                                QS013460
      JYM=MYJ+IFIX(FLOWAT)                                              QS013470
      IYM=MYI+IFIX(FLOWBY)                                              QS013480
      IF(MYJ.EQ.0)MYJ=2                                                 QS013490
      IF(MYI.EQ.0)MYI=IEXIT-2                                           QS013500
      IYM1=IYM-1                                                        QS013510
      IF(IYM1.EQ.0)IYM1=1                                               QS013520
      JYM1=JYM-1                                                        QS013530
      IF(JYM1.EQ.0)JYM1=1                                               QS013540
      IF(I1.EQ.2) GOTO2019                                              QS013550
C     IF(I1.EQ.8) THEN                                                  QS013560
      MACHA=(EMACH(I,J)+EMACH(I,MYJ))/2.                                QS013570
      MACHB=(EMACH(I,J)+EMACH(MYI,J))/2.                                QS013580
      SWICHA=-AMAX1(0.,1./SHIFTM**2-1./MACHA/MACHA)/QUE                 QS013590
      SWICHB=-AMAX1(0.,1./SHIFTM**2-1./MACHB/MACHB)/QUE                 QS013600
                                                                        QS013610
C    RHOSS(2)=MU*DRHODS*DS AT TOP OF ELEMENT                            QS013620
C    RHOSS(8)=MU*DRHODS*DS ON FORWARD, SWEEPING EDGE OF ELEMENT         QS013630
      RHOSS(I1)=SWICHB*SIGNOB*SMALLB*(DUMBX(I,J)-DUMBX(MYI,J))+         QS013640
     1          SWICHA*SIGNOA*SMALLA*(DUMBX(I,J)-DUMBX(I,MYJ))          QS013650
C     SINCE (I1.NE.2)                                                   QS013660
      GOTO 2020                                                         QS013670
2019  MACHA=(ZMACH(I,J)+ZMACH(I,MYJ))/2.                                QS013680
      MACHB=(ZMACH(I,J)+ZMACH(MYI,J))/2.                                QS013690
      SWICHA=-AMAX1(0.,1./SHIFTM**2-1./MACHA/MACHA)/QUE                 QS013700
      SWICHB=-AMAX1(0.,1./SHIFTM**2-1./MACHB/MACHB)/QUE                 QS013710
      RHOSS(I1)=SWICHB*SIGNOB*SMALLB*(DUMBY(I,J)-DUMBY(MYI,J))+         QS013720
     1          SWICHA*SIGNOA*SMALLA*(DUMBY(I,J)-DUMBY(I,MYJ))          QS013730
C     END                                                               QS013740
2020  RHOSS(I1P1)=RHOSS(I1)                                             QS013750
      RHO(I1)=RHO(I1)+DAMP*RHOSS(I1)*ONOFF(I1)                          QS013760
      IF(RHO(I1).LE.0.)RHO(I1)=RHO(I1)-2.*                              QS013770
     1DAMP*RHOSS(I1)*ONOFF(I1)                                          QS013780
      RHO(I1P1)=RHO(I1P1)+DAMP*RHOSS(I1P1)*ONOFF(I1P1)                  QS013790
      IF(RHO(I1P1).LE.0.)RHO(I1P1)=RHO(I1P1)-2.*                        QS013800
     1DAMP*RHOSS(I1P1)*ONOFF(I1P1)                                      QS013810
      PRIORS(7,J)=RHO(1)                                                QS013820
      PRIORS(8,J)=RHO(8)                                                QS013830
3334  FORMAT(2I8,7E13.5)                                                QS013840
C     END                                                               QS013850
C     END                                                               QS013860
694   CONTINUE                                                          QS013870
C     END                                                               QS013880
20001 CONTINUE                                                          QS013890
C     END                                                               QS013900
C     END                                                               QS013910
                                                                        QS013920
```

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                                                                        QS013930
                                                                        QS013940
C     DO ( T'S,Q'S AND RESIDUALS)                                       QS013950
                                                                        QS013960
                                                                        QS013970
C     PROCEDURE ( T'S,Q'S AND RESIDUALS)                                QS013980
                                                                        QS013990
C     NET MASS FLOW TERM                                                QS014000
      ONSUM=0.                                                          QS014010
      FLONET = -RHOUL(2)*ONOFF(7)-RHOUL(3)*ONOFF(6)+PRIORS(9,J)*ONOFF(4 QS014020
     1) + PRIORS(10,J)*ONOFF(5)                                         QS014030
      DO 711 I1=1,8                                                     QS014040
      ONSUM=ONSUM+ONOFF(I1)                                             QS014050
      IF(I1.GE.4.AND.I1.NE.8) GOTO 711                                  QS014060
C     IF(I1  .LT.4.OR.I1.EQ.8) THEN                                     QS014070
      ROSUM=ROSUM+RHO(I1)                                               QS014080
      RHOUL(I1)= RHO(I1)*UN(I1)*LENGTH(I1)* HITE(I1)*ONOFF(I1)          QS014090
      FLONET =FLONET + RHOUL(I1)                                        QS014100
C     END                                                               QS014110
711   CONTINUE                                                          QS014120
      ROAVG=ROSUM/ONSUM                                                 QS014130
      TENOLF(I,J)=FLONET                                                QS014140
      PRIORS(9,J) = -RHOUL(1)                                           QS014150
      PRIORS(10,J) = -RHOUL(8)                                          QS014160
C                                                                       QS014170
C     RESIDUAL TOTAL                                                    QS014180
      R=-FLONET                                                         QS014190
C     END                                                               QS014200
C     IF(BUG) DO (FIRST DEBUG LIST)                                     QS014210
                                                                        QS014220
                                                                        QS014230
C     PROCEDURE (FIRST DEBUG LIST)                                      QS014240
                                                                        QS014250
C      BUG AND BUG3 ARE NOT INCLUDED IN NAMELIST PARAMS. THEY MUST BE   QS014260
C       ADDED OR SET HERE MANUALLY IN ORDER TO ACTIVATE THESE PRINTOUTS.QS014270
                                                                        QS014280
      IF(.NOT.EXIT.OR.MOD(KK,IT).NE.0.OR..NOT.TOP.OR..NOT.BUG) GOTO 2023QS014290
C     IF(EXIT.AND.MOD(KK,IT).EQ.0.AND.TOP.AND.BUG) THEN                 QS014300
      WRITE(6,YTESD)                                                    QS014310
      IF(.NOT.BUG3) GOTO2025                                            QS014320
C     IF(BUG3) THEN                                                     QS014330
      WRITE(6,7001)                                                     QS014340
7001  FORMAT('0ARRAY OF POTENTIAL CORRECTIONS,BLADE SURFACE=FAR RIGHT', QS014350
     1' COLUMN')                                                        QS014360
      DO 732 I2=1,IEXIT                                                 QS014370
732   WRITE(6,9)(DELPSV(I2,J2),J2=I67,M)                                QS014380
      WRITE(6,7002)                                                     QS014390
7002  FORMAT('0ARRAY OF POTENTIAL VALUES,BLADE SURFACE=FAR RIGHT ',     QS014400
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     1'COLUMN')                                                         QS014410
      DO 738 I2=1,IEXIT                                                 QS014420
738   WRITE(6,9)(PHI(I2,J2),J2=I67,M)                                   QS014430
C     END                                                               QS014440
2025  WRITE(6,7003)                                                     QS014450
7003  FORMAT('OARRAY OF RESIDUAL MASS FLOWS,BLADE SURFACE=FAR RIGHT',   QS014460
     1' COLUMN')                                                        QS014470
      DO 745 I2=1,IEXIT                                                 QS014480
745   WRITE(6,9)(TENOLF(I2,J2),J2=I67,M)                                QS014490
      WRITE(6,7004)                                                     QS014500
7004  FORMAT('OARRAY OF MACH NUMBERS,BLADE SURFACE=FAR RIGHT COLUMN')   QS014510
      DO 750 I2=1,IEXIT                                                 QS014520
750   WRITE(6,9)(EMACH(I2,J2),J2=I67,M)                                 QS014530
      REWIND 8                                                          QS014540
      WRITE(8,2) PHI                                                    QS014550
C     END                                                               QS014560
9     FORMAT(1H ,14E9.3)                                                QS014570
C     END                                                               QS014580
                                                                        QS014590
                                                                        QS014600
                                                                        QS014610
C     DO ( DELPHI  COEFFICIENTS AND TRANSPOSED TERMS)                   QS014620
                                                                        QS014630
C     PROCEDURE ( DELPHI  COEFFICIENTS AND TRANSPOSED TERMS)            QS014640
C                                                                       QS014650
C     AIJP1*DELPHI(I,J+1)+AIJ*DELPHI(I,J)+AIJM1*DELPHI(I,J-1)= R + BIGZ QS014660
                                                                        QS014670
C                                                                       QS014680
2023  DELPM1(2) = DELPHI(J)                                             QS014690
      IF(I.EQ.2)DELPM1(2)=DELPSV(IEXIT-1,J)                             QS014700
      IF(KK.GT.2.AND.MOD(KK,IT).NE.0) GOTO 2029                         QS014710
C     IF(KK.LE.2.OR.MOD(KK,IT).EQ.0) THEN                               QS014720
      AIJP1=(T(2)*RHO(2)+T(3)*RHO(3))/ZETDF1                            QS014730
      AIJM1=(T(6)*RHO(6)+T(7)*RHO(7))/ZETDF2                            QS014740
      TT18=(T(1)*RHO(1)+T(8)*RHO(8))/ETADF1                             QS014750
      ZIM1J=(T(4)*RHO(4)+T(5)*RHO(5))/ETADF2                            QS014760
      AIJ=-1.*(AIJM1+AIJP1+TT18+ZIM1J)                                  QS014770
      ZIP1J=0.                                                          QS014780
      ZJP1=0.                                                           QS014790
      ZJM1=0.                                                           QS014800
                                                                        QS014810
C    SAVE COEFFICIENTS UNTIL THE NEXT TIME DENSITY IS UPDATED (WHEN KK ISQS014820
C    DIVISIBLE BY IT).                                                  QS014830
      SUPERG(43,J,I)=AIJ                                                QS014840
      SUPERG(44,J,I)=AIJM1                                              QS014850
      SUPERG(45,J,I)=AIJP1                                              QS014860
      SUPERG(46,J,I)=ZIM1J                                              QS014870
      ZIM1J=ZIM1J*DELPM1(2)                                             QS014880
```

```
C     SINCE (KK.LE.2.OR.MOD(KK,IT).EQ.0)
      GOTO 2030
C   IF ITERATION COUNT EXCEEDS 2 AND IS NOT DIVISIBLE BY IT, OBTAIN
C   COEFFICIENTS FROM THE LAST CALCULATION.
2029  AIJ=SUPERG(43,J,I)
      AIJM1=SUPERG(44,J,I)
      AIJP1=SUPERG(45,J,I)
      ZIM1J=SUPERG(46,J,I)
      ZIM1J=ZIM1J*DELPM1(2)
      ZJP1=0.
      ZJM1=0.
C     END
2030  BIGZ = -(ZIP1J +ZIM1J + ZJP1 + ZJM1)
      IF(J.EQ.4)BIGZ=BIGZ-AIJM1*DELPSV(IEXIT+2-I,5)
      TRANSP = R +BIGZ

C    ELIMINATE CHANGES TO PHI(BY ZEROING COEFFICIENTS)ON ALL DUMMY LINES
C    BEYOND  PERIODIC LINE.
      IF(.NOT.(J.LT.4.OR.(J.LE.5.AND.
     1(I.LE.3.OR.I.GE.IEXIT-1.OR.I.EQ.NOZ-1.OR.
     1I.EQ.NOZ.OR.I.EQ.NOZ+1)))) GOTO 2031
C     AIJ=0.
      AIJM1=0.
      AIJP1=0.
      TRANSP=0.

C     STORE COEFFICIENTS FOR LATER TRIDIAGONAL SOLUTION OF THIS LINE
2031  PRIORS(11,J)=AIJ
      PRIORS(12,J)=AIJP1
      PRIORS(13,J)=AIJM1
      PRIORS(14,J)=TRANSP


C   PROCEED TO NEXT VALUE OF J ON THIS RADIATING LINE
      IF(.NOT.TOP)GOTO275
C     END



C     DO (FORWARD ELIMINATION)


C     PROCEDURE (FORWARD ELIMINATION)

      DO 828 J=1,M
      JM1=J-1
      IF(JM1.EQ.0) JM1=2
```

```
      BOTTOM =  .FALSE.                                                 QS015370
      TOP    =  .FALSE.                                                 QS015380
      BLADE  =  .FALSE.                                                 QS015390
      IF(J.EQ.1)  BOTTOM =.TRUE.                                        QS015400
      IF(J.EQ.M)  TOP =.TRUE.                                           QS015410
      BLADE = TOP                                                       QS015420
                                                                        QS015430
C    RECOVER COEFFICIENTS                                               QS015440
      AIJ=PRIORS(11,J)                                                  QS015450
      AIJP1=PRIORS(12,J)                                                QS015460
      AIJM1=PRIORS(13,J)                                                QS015470
      TRANSP=PRIORS(14,J)                                               QS015480
      IF(BOTTOM) GOTO 828                                               QS015490
C     IF(.NOT.BOTTOM) THEN                                              QS015500
      FFAC=AIJ-AIJM1*E(JM1)                                             QS015510
      E(J)=  +AIJP1/FFAC                                                QS015520
      F(J)=   (TRANSP -  AIJM1*F(JM1))/FFAC                             QS015530
3333  FORMAT(9E13.5)                                                    QS015540
C     END                                                               QS015550
                                                                        QS015560
828   CONTINUE                                                          QS015570
C     END                                                               QS015580
                                                                        QS015590
                                                                        QS015600
                                                                        QS015610
C     IF(I.NE.1)                                                        QS015620
C    1DO  (BACK  SUBSTITUTION)                                          QS015630
                                                                        QS015640
                                                                        QS015650
C     PROCEDURE (BACK  SUBSTITUTION)                                    QS015660
                                                                        QS015670
      DELPHI(M)=F(M)                                                    QS015680
      OV=OVEREL                                                         QS015690
      IF(KKK.LT.NOTYET)OV=UNDERL                                        QS015700
      IF(EMACH(I,M).GE.1.)OV=SUPREL*(1.-D(M)*(1.-CI))                   QS015710
      DELPSV(I,M)=DELPHI(M)*OV                                          QS015720
      J=M-1                                                             QS015730
856   IF(J.LT.1)GOTO857                                                 QS015740
3335  FORMAT(3I6,9E12.5)                                                QS015750
      BOTTOM =  .FALSE.                                                 QS015760
      TOP    =  .FALSE.                                                 QS015770
      BLADE  =  .FALSE.                                                 QS015780
      IF(J.EQ.1)  BOTTOM =.TRUE.                                        QS015790
      IF(J.EQ.M)  TOP =.TRUE.                                           QS015800
      BLADE = TOP                                                       QS015810
      IF(.NOT.BOTTOM)  DELPHI(J)=-E(J)*DELPHI(J+1)+F(J)                 QS015820
      OV=OVEREL                                                         QS015830
      IF(KKK.LT.NOTYET)OV=UNDERL                                        QS015840
```

```
      IF(EMACH(I,J).GE.1.)OV=SUPREL*(1.-D(J)*(1.-CI))                   QS015850
      DELPSV(I,J)= DELPHI(J)*OV                                         QS015860
      J=J-1                                                             QS015870
      GOTO0856                                                          QS015880
857   CONTINUE                                                          QS015890
C     END                                                               QS015900
      J=0                                                               QS015910
                                                                        QS015920
                                                                        QS015930
C       GO TO NEXT RADIATING LINE                                       QS015940
                                                                        QS015950
      IF(.NOT.EXIT)GOTO272                                              QS015960
      TOT=0.                                                            QS015970
                                                                        QS015980
                                                                        QS015990
                                                                        QS016000
                                                                        QS016010
                                                                        QS016020
C     IF ALL LINES ARE COMPLETED, THEN                                  QS016030
C     DO (UPDATE OF FIELD VARIABLES)                                    QS016040
                                                                        QS016050
                                                                        QS016060
C     PROCEDURE (UPDATE OF FIELD VARIABLES)                             QS016070
                                                                        QS016080
      DO 871 I =2,IEXIT                                                 QS016090
      DO 871 J1=1,M                                                     QS016100
      PHI(I ,J1)= PHI(I ,J1)+DELPSV(I ,J1)                              QS016110
871   IF(J1.GE.4.AND.I.GT.1.AND.(ABS(DELPSV(I,J1)).LT.TEST*AVGFAC*GUESS QS016120
     1/FLOAT(IEXIT-1)/FLOAT(M-3).OR.KKK.LT.NOTYET))                     QS016130
     1TOT=TOT+ABS(DELPSV(I,J1))                                         QS016140
      SSFAC=RADLE/FIXR*S*AQINF1*SIN(LAMDAO+BETA1)                       QS016150
      DO 880 I1=2,IEXIT                                                 QS016160
      IF(I1.EQ.NOZ) GOTO 880                                            QS016170
C     IF(I1.NE.NOZ) THEN                                                QS016180
      SFAC=SSFAC*FLOAT(ISIGN(1,I1-NOZ))                                 QS016190
                                                                        QS016200
C      CORRECT THE DUMMY LINES BEYOND PERIODIC BOUNDARY USING PERIODICITQS016210
C     Y                                                                 QS016220
C      CONDITION.                                                       QS016230
      DO 878 J1=1,3                                                     QS016240
878   PHI(I1,J1)=PHI(IEXIT+2-I1,8-J1)+SFAC                              QS016250
C     END                                                               QS016260
880   CONTINUE                                                          QS016270
                                                                        QS016280
C       UPDATE DUMMY LINES ON EACH SIDE OF BRANCH CUT                   QS016290
                                                                        QS016300
      DO 890 J1=1,M                                                     QS016310
      PHI(1,J1)=                                                        QS016320
```

```
     1PHI(IEXIT-1,J1)-CIRCO                                             QS016330
C    1PHI(IEXIT-1,J1)-RADLE/FIXR*S*(AQINF1*SIN(LAMDA0+BETA1)-AQINF2*SIN(QS016340
C    1LAMDA0+BETA2)/P1OP2)                                              QS016350
890   PHI(IEXIT+1,J1)=PHI(3,J1)+                                        QS016360
     1CIRCO                                                             QS016370
C    1     RADLE/FIXR*S*(AQINF1*SIN(LAMDA0+BETA1)-AQINF2*SIN(LAMDA0+    QS016380
C    1BETA2)/P1OP2)                                                     QS016390
C     END                                                               QS016400
                                                                        QS016410
                                                                        QS016420
                                                                        QS016430
C     DO (CONVERGENCE TESTS)                                            QS016440
                                                                        QS016450
                                                                        QS016460
C      PROCEDURE (CONVERGENCE TESTS)                                    QS016470
                                                                        QS016480
      RELAXD=.FALSE.                                                    QS016490
      NOZO2=NOZ/2                                                       QS016500
      MO2=M/2                                                           QS016510
      AVGFAC=FLOAT(IEXIT-2)*FLOAT(M-3)*ABS(PHI(NOZO2,MO2))              QS016520
      TEST=TOT/AVGFAC                                                   QS016530
      CIRCN=PHI(IEXIT,M)-PHI(2,M)                                       QS016540
      DCIRC=(CIRCN-CIRCO)/CIRCOO                                        QS016550
      IF(TOL.GT.0..AND.TOL.LT.1..AND.ABS(TEST).LT.TOL)RELAXD =.TRUE.    QS016560
      IF(TOL.GT.1..AND.KK.GE.IFIX(TOL))RELAXD=.TRUE.                    QS016570
      TRUNC=ABS(TOL)                                                    QS016580
      IF(TOL.LT.0..AND.ABS(DCIRC).LT.TRUNC.AND.KKK.GT.50)RELAXD=.TRUE.  QS016590
      IF(KKK.GE.KKMAX)RELAXD=.TRUE.                                     QS016600
      TESMAC=0.                                                         QS016610
      DO 909 I=2,IEXIT                                                  QS016620
      RF=(.5*(DUMBX(I,M)+DUMBX(I-1,M)))**(1./2./EXPO)                   QS016630
      HIMAC=.5*(EMACH(I,M)+EMACH(I-1,M))*RF                             QS016640
      IF(HIMAC.GT.TESMAC.AND.ABS(X(I,M)/COS(LAMDA0))                    QS016650
     1.LT..44)TESMAC=HIMAC                                              QS016660
909   CONTINUE                                                          QS016670
      IF(MOD(KK,IT).EQ.0.OR.BUG.OR.RELAXD)                              QS016680
     1WRITE(6,99) KK,TEST,TRANSP,TESMAC,CIRCN,DCIRC,OVEREL,SUPREL       QS016690
99    FORMAT(1H ,4X,I4,4X,7E14.6)                                       QS016700
C     END                                                               QS016710
      I=0                                                               QS016720
                                                                        QS016730
                                                                        QS016740
                                                                        QS016750
      IF(.NOT.RELAXD)GOTO269                                            QS016760
                                                                        QS016770
                                                                        QS016780
C      OTHERWISE                                                        QS016790
C     DO (SURFACE FLOW CALCULATION FOR FINISHED GRID)                   QS016800
```

```
                                                                        QS016810
                                                                        QS016820
C     PROCEDURE (SURFACE FLOW CALCULATION FOR FINISHED GRID)            QS016830
                                                                        QS016840
      WRITE(6,781) M3,ITIEX                                             QS016850
      ICOUNT=0                                                          QS016860
      IDEX=1                                                            QS016870
      DO 937 I=1,IEXIT                                                  QS016880
      I1M=I-1                                                           QS016890
      IM1=I1M                                                           QS016900
      IF(IM1.EQ.0)IM1=2                                                 QS016910
      FIRSTJ=M-2                                                        QS016920
      LINEI=I                                                           QS016930
                                                                        QS016940
                                                                        QS016950
C     DO (VFLOCITY CALCULATION ALONG RADIATING LINE)                    QS016960
      CALL SPEEDS(LINEI,FIRSTJ)                                         QS016970
                                                                        QS016980
                                                                        QS016990
937   IF(I1M.GT.0)                                                      QS017000
     1WRITE(6,782)I1M,XOCX,FADBOP,X(I,M),Y(I,M),D(M),BOPR,              QS017010
     1PHI(I,M),E(M),F(M),DELPHI(M)                                      QS017020
781   FORMAT(1H0/1H0,22X,                                               QS017030
     1'FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE ',I3,            QS017040
     1' BY ',I3,' MESH '//' RADIATING',50X,'  STATIC   '/'  LINE NO. ', QS017050
     1'     X/CX      Y/CX      X         Y         MACH   PRES ',       QS017060
     1'COEF     PHI       XVEL       YVEL      DENSITY '/)              QS017070
782   FORMAT(I6,4X,10F10.5)                                             QS017080
C     END                                                               QS017090
                                                                        QS017100
                                                                        QS017110
      RETURN                                                            QS017120
                                                                        QS017130
                                                                        QS017140
                                                                        QS017150
                                                                        QS017160
      ENTRY KEEPER                                                      QS017170
                                                                        QS017180
                                                                        QS017190
C     DO (OUTPUT OF PHI AND CALCULATION OF FINAL VELOCITY FIELD)        QS017200
                                                                        QS017210
                                                                        QS017220
C     PROCEDURE (OUTPUT OF PHI AND CALCULATION OF FINAL VELOCITY FIELD) QS017230
                                                                        QS017240
      REWIND 7                                                          QS017250
10    FORMAT(5E15.8)                                                    QS017260
                                                                        QS017270
      ENT=1.                                                            QS017280
```

```
      EXI=1.
      IF(ALLOUT)WRITE(6,131) M3,ITIEX
131   FORMAT(1H1,38X,' CALCULATED FLOW FIELD AT ALL GRID POINTS '/1H0,
     138X,
     1'SURFACE CONTOUR NO.  1  = PERIODIC BOUNDARY'/40X,'SURFACE CONT',
     1'OUR NO. ',
     1I3,' = BLADE SURFACE'/1H0,31X,' RADIATING LINE NO.  1 BEGINS AT',
     1' DOWNSTREAM',
     1' INFINITY '/42X,' AND IS REPEATED AS LINE NO. ',I3)
      IF(ALLOUT)WRITE(6,13)
13    FORMAT(1H0,15X,'SURFACE ',74X,'FLOW     STATIC'/16X'CONTOUR    ',
     1'X/CX        Y/CX      ',
     1'   PHI        XVEL        YVEL     DENSITY      MACH       ANGLE',
     1'   PRES COEF'/15X,' NUMBER')
      IDEX=1
      ICOUNT=0
      DO 969 I=1,IEXIT
      I1M=I-1
      IF(I.GT.1.AND.ALLOUT)WRITE(6,14) I1M
14    FORMAT('ORADIATING LINE'/'     NUMBER ',I3)
      IM1= I-1
      IF(IM1.EQ.0) IM1=2
      FIRSTJ=1
      LINEI=I


C     DO (VELOCITY CALCULATION ALONG RADIATING LINE)
      CALL SPEEDS(LINEI,FIRSTJ)


969   CONTINUE
      DO 972 I=2,IEXIT
972   E(I)=.5*(DELPSV(I,4)+DELPSV(IEXIT+2-I,4))
      DO 975 I=2,IEXIT
975   DELPSV(I,4)=E(I)
      REWIND 13
      MM3=M-3
      NNOZ=NOZ-1

C      WRITE THE PLOT DATA SAVE FILE

      WRITE(13,1)  NNOZ,MM3
1     FORMAT(2I5)
      WRITE(13,2)((X(I,J),I=2,NZZ),J=4,M),((Y(I,J),I=2,NZZ),J=4,M)
      WRITE(13,2)((DUMBX(I,J),I=2,NZZ),J=4,M),((DUMBY(I,J),I=2,NZZ),
     1J=4,M),((DELPSV(I,J),I=2,NZZ),J=4,M)
      WRITE(13,2) ((TENOLF(I,J),I=2,NZZ),J=4,M)
```

```
                                                                        QS017770
      IF(BUG3)                                                          QS017780
     1WRITE(6,2)((X(I,J),I=2,NZZ),J=4,M),((Y(I,J),I=2,NZZ),J=4,M)        QS017790
      IF(BUG3)                                                          QS017800
     1WRITE(6,2)((DUMBX(I,J),I=2,NZZ),J=4,M),((DUMBY(I,J),I=2,NZZ),     QS017810
     1J=4,M)                                                            QS017820
C     END                                                               QS017830
                                                                        QS017840
                                                                        QS017850
      RETURN                                                            QS017860
                                                                        QS017870
                                                                        QS017880
                                                                        QS017890
                                                                        QS017900
                                                                        QS017910
                                                                        QS017920
                                                                        QS017930
      END                                                               QS017940
      SUBROUTINE SPEEDS(I,MM2)                                          QS017950
                                                                        QS017960
C      VELOCITY CALCULATION ALONG ONE RADIATING LINE (I), BEGINNING AT JQS017970
C     =                                                                 QS017980
C      MM2 AND GOING TO J=M (THE BLADE SURFACE).    ARRAYS DELPHI, DELPSQS017990
C     V                                                                 QS018000
C      D,E,F,PRIORS,DUMBY, AND DUMBX ARE REUSED (OVERWRITTEN) IN THE PROQS018010
C     CESS.                                                             QS018020
                                                                        QS018030
                                                                        QS018040
                                                                        QS018050
                                                                        QS018060
      LOGICAL INLET,BLADE,EXIT,BOTTOM,TOP                               QS018070
      LOGICAL DOSURF,SMOOTH,FINEST,RESTAR,ALLOUT                        QS018080
      REAL LAB,LAD,MINF,LENGTH,JACOB,LAMDAO                             QS018090
      REAL MACH(8)                                                      QS018100
      DOUBLE PRECISION CAPK,CAPKP                                       QS018110
      COMMON/PARAM/RESTAR,NOZIN,BETA1,BETA2,QINF1,CI,CII,GAMMA,MINF,EM  QS018120
     1,DELTA,BETA,TOL,BUG,BUG2,BUG3,IT,GUESS,OVEREL,FIXR,NOWREL,NOTYET  QS018130
     1,DAMP,SUPREL,S,WAKE,B2OB1,UNDERL,RADRAT,RADLE,OMEGA,FLOCO,VAXIAL, QS018140
     1ALLOUT                                                            QS018150
      COMMON/QUASI/ RADIUS(100,30),HEIGHT(100,30)                       QS018160
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)    QS018170
      COMMON/GEOM2/ZETA(100),ETA(100)                                   QS018180
      COMMON/CROSS/  ZMACH(100,30)                                      QS018190
      COMMON/GEOM/NOZ,M,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK,       QS018200
     1CAPKP,PI                                                          QS018210
     1,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS                          QS018220
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL               QS018230
     1,FINEST                                                           QS018240
```

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      COMMON/CALVEL/FAKEFI(4,6),FAKFI(4,6),RHOCON,QLIM,EXPO,ROTATN,     QS018250
     1ROTROT,IM1,IEXIT,PRIORS(14,30),INDEX(100,30),I1DEX(32),FAKEU(100),QS018260
     1FAKEV(100),ICOUNT,IDEX,AMY,AMZ                                    QS018270
      COMMON/VELOUT/D(100),E(100),F(100),DELPHI(100),TENOLF(100,30),    QS018280
     1DUMBX(100,30),DUMBY(100,30),BOPR,FADBOP,XOCX,KK                   QS018290
      DIMENSION RHOSS(8), FI1(8),FI2(3),FI3(3),FI9(8),SPAN(8),          QS018300
     1EMACH(100,30)                                                     QS018310
     2,COSX(8),COSY(8),LENGTH(8),DEDX(8),DZDX(8),DEDY(8),               QS018320
     3DZDY(8),T(8),DPHIDZ(8),DPHIDE(8),U(8),V(8),UN(8),RHO(8),          QS018330
     4RHOUL(8),ONOFF(8),DELPM1(3)                                       QS018340
     5,HITE(8)                                                          QS018350
                                                                        QS018360
      COMMON/HIBALL/ SUPERG(46,30,100)                                  QS018370
                                                                        QS018380
      XDIF(A,B,C,D)=.5*(A+B-C-D)                                        QS018390
                                                                        QS018400
                                                                        QS018410
                                                                        QS018420
                                                                        QS018430
                                                                        QS018440
C     PROCEDURE (VELOCITY CALCULATION ALONG RADIATING LINE)             QS018450
C     DO (AXIAL LOCATION INDICATORS)                                    QS018460
      INLET=.FALSE.                                                     QS018470
      EXIT  = .FALSE.                                                   QS018480
      IF(I.EQ.1) INLET =.TRUE.                                          QS018490
      IF( I.EQ. IEXIT) EXIT=.TRUE.                                      QS018500
      XLOW=0.                                                           QS018510
      XHI  =0.                                                          QS018520
      YLOW=1.E10                                                        QS018530
      DO 1111 I1=1,IEXIT                                                QS018540
      IF(XLOW.LT.X(I1,M))GOTO11                                         QS018550
      XLOW=X(I1,M)                                                      QS018560
11    IF(XHI.GT.X(I1,M))GOTO111                                         QS018570
      XHI=X(I1,M)                                                       QS018580
111   IF(YLOW.LT.Y(I1,M))GOTO1111                                       QS018590
      YLOW=Y(I1,M)                                                      QS018600
1111  CONTINUE                                                          QS018610
      DO 1427 J=MM2,M                                                   QS018620
      J3M=J-3                                                           QS018630
      JM1=J-1                                                           QS018640
      IF(JM1.EQ.0) JM1=2                                                QS018650
C     DO (VERTICAL LOCATION INDICATORS)                                 QS018660
      BOTTOM = .FALSE.                                                  QS018670
      TOP    = .FALSE.                                                  QS018680
      BLADE  = .FALSE.                                                  QS018690
      IF(J.EQ.1) BOTTOM =.TRUE.                                         QS018700
      IF(J.EQ.M) TOP =.TRUE.                                            QS018710
      BLADE = TOP                                                       QS018720
```

```
C     DO (GEOMETRY ADVANCE)                                             QS018730
      SPAN(1)=XDIF(RADIUS(I,J),RADIUS(I+1,J),0.,0.)                     QS018740
      IF(I.EQ.IEXIT)SPAN(1)=RADIUS(I,J)                                 QS018750
      SPAN(1)=SPAN(1)/FIXR                                              QS018760
      SPAN(2)=XDIF(RADIUS(I,J),RADIUS(I,J+1),0.,0.)                     QS018770
      SPAN(2)=SPAN(2)/FIXR                                              QS018780
      SPAN(3)=SPAN(2)                                                   QS018790
      SPAN(8)=SPAN(1)                                                   QS018800
      COSX(1)=SUPERG(1,J,I)                                             QS018810
      COSX(2)=SUPERG(2,J,I)                                             QS018820
      COSX(3)=SUPERG(3,J,I)                                             QS018830
      COSX(8)=SUPERG(4,J,I)                                             QS018840
      COSY(1)=SUPERG(5,J,I)                                             QS018850
      COSY(2)=SUPERG(6,J,I)                                             QS018860
      COSY(3)=SUPERG(7,J,I)                                             QS018870
      COSY(8)=SUPERG(8,J,I)                                             QS018880
      LENGTH(1)=SUPERG(9,J,I)                                           QS018890
      LENGTH(2)=SUPERG(10,J,I)                                          QS018900
      LENGTH(3)=SUPERG(11,J,I)                                          QS018910
      LENGTH(8)=SUPERG(12,J,I)                                          QS018920
      EXDIF1=SUPERG(13,J,I)                                             QS018930
      EXDIF2=SUPERG(14,J,I)                                             QS018940
      YDIF1=SUPERG(15,J,I)                                              QS018950
      YDIF2=SUPERG(16,J,I)                                              QS018960
      SLEN=SUPERG(17,J,I)                                               QS018970
      SLEN2=SUPERG(18,J,I)                                              QS018980
      ZETDF1=SUPERG(19,J,I)                                             QS018990
      ZETDF2=SUPERG(20,J,I)                                             QS019000
      ETADF1=SUPERG(21,J,I)                                             QS019010
      ETADF2=SUPERG(22,J,I)                                             QS019020
      DEDX(1)=SUPERG(23,J,I)                                            QS019030
      DEDX(2)=SUPERG(24,J,I)                                            QS019040
      DEDX(3)=SUPERG(25,J,I)                                            QS019050
      DEDX(8)=SUPERG(26,J,I)                                            QS019060
      DEDY(1)=SUPERG(27,J,I)                                            QS019070
      DEDY(2)=SUPERG(28,J,I)                                            QS019080
      DEDY(3)=SUPERG(29,J,I)                                            QS019090
      DEDY(8)=SUPERG(30,J,I)                                            QS019100
      DZDX(1)=SUPERG(31,J,I)                                            QS019110
      DZDX(2)=SUPERG(32,J,I)                                            QS019120
      DZDX(3)=SUPERG(33,J,I)                                            QS019130
      DZDX(8)=SUPERG(34,J,I)                                            QS019140
      DZDY(1)=SUPERG(35,J,I)                                            QS019150
      DZDY(2)=SUPERG(36,J,I)                                            QS019160
      DZDY(3)=SUPERG(37,J,I)                                            QS019170
      DZDY(8)=SUPERG(38,J,I)                                            QS019180
      T(1)=SUPERG(39,J,I)                                               QS019190
      T(2)=SUPERG(40,J,I)                                               QS019200
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      T(3)=SUPERG(41,J,I)                                                QS019210
      T(8)=SUPERG(42,J,I)                                                QS019220
C     CELL  II,  POINT  C                                                QS019230
      T(5) =   PRIORS(1,J)*ONOFF(5)                                      QS019240
      T(4) =   PRIORS(2,J)*ONOFF(4)                                      QS019250
      PRIORS(1,J)  = - T(8)                                              QS019260
      PRIORS(2,J)  = - T(1)                                              QS019270
C     DO (FIELD GRADIENTS)                                               QS019280
C     CELL II,  POINT C                                                  QS019290
      DO 1214 I1=1,3                                                     QS019300
      FI1(I1)=PHI(I+1,J)                                                 QS019310
      FI2(I1)=PHI(I+1,J+1)                                               QS019320
      FI3(I1)=PHI(I  ,J+1)                                               QS019330
 1214 FI9(I1)=PHI(I  ,J  )                                               QS019340
      FI4    =PHI(IM1,J+1)                                               QS019350
      FI5    =PHI(IM1,J  )                                               QS019360
      FI6    =PHI(IM1,JM1)                                               QS019370
      FI7    =PHI(I  ,JM1)                                               QS019380
      FI8    =PHI(I+1,JM1)                                               QS019390
      FI1(8)=PHI(I+1,J)                                                  QS019400
      FI9(8)=PHI(I  ,J)                                                  QS019410
      I10=I-IEXIT+3                                                      QS019420
C     END                                                                QS019430
C     END                                                                QS019440
C     CELL I , POINT A                                                   QS019450
 2501 DPHIDZ(1)= XDIF(FI3(1),FI2(1),FI9(1),FI1(1))/ZETDF1                QS019460
      DPHIDE(1) =   (FI1(1)-FI9(1))/ETADF1                               QS019470
C     CELL I, POINT B                                                    QS019480
      DPHIDE(2)=XDIF(FI1(2),FI2(2),FI9(2),FI3(2)) /ETADF1                QS019490
      DPHIDZ(2)=(FI3(2)-FI9(2))/ZETDF1                                   QS019500
C     CELL II, POINT B                                                   QS019510
      DPHIDE(3)=XDIF(FI5,FI4,FI9(3),FI3(3)) /ETADF2                      QS019520
      DPHIDZ(3)=(FI3(3)-FI9(3))/ZETDF1                                   QS019530
C     CELL IV, POINT A                                                   QS019540
      DPHIDE(8) =   (FI1(8)-FI9(8))/ETADF1                               QS019550
      DPHIDZ(8) =XDIF(FI7,FI8,FI9(8),FI1(8))/ZETDF2                      QS019560
C     DO (BOUNDARY CONDITION SWITCHES)                                   QS019570
      DO 1306 I1=1,8                                                     QS019580
 1306 ONOFF(I1)=1.                                                       QS019590
      IF(.NOT.INLET.AND..NOT.BOTTOM.AND..NOT.TOP  ) GOTO2060             QS019600
      IF(TOP)IS=1                                                        QS019610
      IF(INLET)IS=3                                                      QS019620
      IF(BOTTOM)IS=5                                                     QS019630
      IE=IS+3                                                            QS019640
      DO 2059 I1=IS,IE                                                   QS019650
 2059 ONOFF(I1)=0.                                                       QS019660
C     DO (VELOCITIES AND DENSITIES)                                      QS019670
 2060 U(6) = U(3)                                                        QS019680
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      V(6) = V(3)                                                       QS019690
      U(7) = U(2)                                                       QS019700
      V(7) = V(2)                                                       QS019710
      DO 1337 I1 =1,8                                                   QS019720
      IF(I1.GE.4.AND.I1.NE.8) GOTO 1337                                 QS019730
C     IF(I1.LT.4.OR.I1.EQ.8) THEN                                       QS019740
      U(I1)=DPHIDE(I1)*DEDX(I1)+ DPHIDZ(I1)*DZDX(I1)                    QS019750
      V(I1)=DPHIDE(I1)*DEDY(I1)+ DPHIDZ(I1)*DZDY(I1)                    QS019760
      IF(INDEX(I,J).EQ.0)GOTO5411                                       QS019770
      ICOUNT=ICOUNT+1                                                   QS019780
      I1S=I1DEX(ICOUNT)                                                 QS019790
      IF(I1.LE.I1S)I1P=I1S                                              QS019800
      IDIF=INDEX(I,J)+I1S-1                                             QS019810
      IF(I1S.EQ.1.AND.I1P.EQ.IDIF)I1P=8                                 QS019820
      IF(I1.NE.I1P)GOTO5410                                             QS019830
      IF(I1P.GT.IDIF.AND.I1P.NE.8)GOTO5410                              QS019840
      V(I1)=FAKEV(IDEX)                                                 QS019850
      U(I1)=FAKEU(IDEX)                                                 QS019860
      IDEX=IDEX+1                                                       QS019870
      I1P=I1P+1                                                         QS019880
5410  IF(I1.NE.8)ICOUNT=ICOUNT-1                                        QS019890
5411  V(I1)=V(I1)-SPAN(I1)*FIXR/RADLE*ROTATN                            QS019900
      UN(I1)=U(I1)*COSX(I1)+V(I1)*COSY(I1)                              QS019910
C     END                                                               QS019920
1337  CONTINUE                                                          QS019930
      IF(.NOT.TOP) GOTO 2064                                            QS019940
C     IF(TOP) THEN                                                      QS019950
C     U(8)=(DPHIDE(8)*ETADF1-RADIUS(I,J)/RADLE*ROTATN*YDIF1)*EXDIF1/SLENQS019960
C     V(8)=(DPHIDE(8)*ETADF1-RADIUS(I,J)/RADLE*ROTATN*YDIF1)*YDIF1/SLEN QS019970
      ROTATX=ROTATN*RADIUS(I,J)/RADLE                                   QS019980
C     U8=SQRT((DPHIDE(8)*ETADF1/EXDIF1)**2+(DPHIDE(8)*ETADF1/YDIF1-     QS019990
C    1-ROTATX)**2)*EXDIF1/SQRT(SLEN)                                    QS020000
      U8=SQRT(U(8)*U(8)+V(8)*V(8))*ABS(EXDIF1)/SQRT(SLEN)               QS020010
      U(8)=SIGN(U8,U(8))                                                QS020020
      V(8)=U(8)*YDIF1/EXDIF1                                            QS020030
      UN(8)=U(8)*COSX(8)+V(8)*COSY(8)                                   QS020040
C     END                                                               QS020050
2064  U(4) =  PRIORS(3,J)                                               QS020060
      U(5) =  PRIORS(4,J)                                               QS020070
      V(4) =  PRIORS(5,J)                                               QS020080
      V(5) =  PRIORS(6,J)                                               QS020090
      PRIORS(3,J)=U(1)                                                  QS020100
      PRIORS(4,J)=U(8)                                                  QS020110
      PRIORS(5,J)=V(1)                                                  QS020120
      PRIORS(6,J)=V(8)                                                  QS020130
      RHO(7)=RHO(2)                                                     QS020140
      RHO(6)=RHO(3)                                                     QS020150
      RHO(4)=PRIORS(7,J)                                                QS020160
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      RHO(5)=PRIORS(8,J)                                                QS020170
      ONSUM=0.                                                          QS020180
      DO 1391 I1=1,8                                                    QS020190
C     IF(KK.LE.2.OR.MOD(KK,2).EQ.0) THEN                                QS020200
      IF(I1.GE.4.AND.I1.NE.8) GOTO 2066                                 QS020210
C     IF(I1.LT.4.OR.I1.EQ.8) THEN                                       QS020220
      RHOFAC=1.                                                         QS020230
      RHO(I1)=1.                                                        QS020240
      IF((I.EQ.2.OR.I.EQ.IEXIT).AND.J.LE.4.AND.ROTATN.NE.0.             QS020250
     1.OR.KK.LE.NOTYET) GOTO 2066                                       QS020260
      QSQAR=U(I1)*U(I1)+(V(I1)*V(I1))                                   QS020270
      IF(QSQAR.GE.QLIM)QSQAR=.99*QLIM                                   QS020280
      RHOFAC=RHOCON*(1.-QSQAR)*ONOFF(I1)+1.                             QS020290
      RHO(I1)=1.-AMZ*(QSQAR-1.)+AMY*(QSQAR-1.)*(QSQAR-1.)               QS020300
      IF(QSQAR.LT..65.OR.QSQAR.GT.1.44)RHO(I1)=RHOFAC**EXPO             QS020310
      ROTATX=SPAN(I1)*FIXR                                              QS020320
      IF(ROTROT.NE.0..AND.J.GT.3)                                       QS020330
     1RHO(I1)=(RHO(I1)**(1./EXPO)+RHOCON*ROTROT*((ROTATX/RADLE)         QS020340
     1**2-1.)*ONOFF(I1))**EXPO                                          QS020350
C     END                                                               QS020360
C     END                                                               QS020370
2066  QSQAR=U(I1)*U(I1)+V(I1)*V(I1)                                     QS020380
      IF(I.GT.1)                                                        QS020390
     1MACH(I1)=MINF*SQRT(QSQAR)/RHO(I1)**(1./EXPO)                      QS020400
      IF(MACH(I1).GT.2.)MACH(I1)=2.                                     QS020410
1391  CONTINUE                                                          QS020420
      PRIORS(7,J)=RHO(1)                                                QS020430
      PRIORS(8,J)=RHO(8)                                                QS020440
      IF(I.LE.1.OR.J.LE.3) GOTO 1427                                    QS020450
C     IF(I.GT.1.AND.J.GT.3) THEN                                        QS020460
      E(J)=1.                                                           QS020470
      F(J)=0.                                                           QS020480
      ONSUM=ONOFF(1)+ONOFF(8)+ONOFF(4)+ONOFF(5)                         QS020490
      E(J)=(U(1)*ONOFF(1)+U(8)*ONOFF(8)+U(4)*ONOFF(4)+U(5)              QS020500
     1*ONOFF(5))/ONSUM                                                  QS020510
      F(J)=(V(1)*ONOFF(1)+V(8)*ONOFF(8)+V(4)*ONOFF(4)+V(5)              QS020520
     1*ONOFF(5))/ONSUM                                                  QS020530
      DUMBX(I,J)=E(J)                                                   QS020540
      DUMBY(I,J)=F(J)                                                   QS020550
      EFFAC=1.-E(J)*E(J)-F(J)*F(J)                                      QS020560
      DELPHI(J)=(RHO(1)*ONOFF(1)+RHO(8)*ONOFF(8)+RHO(4)*ONOFF(4)+RHO(5) QS020570
     1*ONOFF(5))/ONSUM                                                  QS020580
      D(J)=0.                                                           QS020590
      D(J)=MINF*SQRT((F(J)*F(J)+E(J)*E(J))/DELPHI(J)**(1./EXPO))        QS020600
      IF(J.LE.6.AND.(I.LE.4.OR.I.GE.IEXIT-2)) D(J)=EM                   QS020610
      IF(J.LE.6.AND.I.GE.NOZ-1.AND.I.LE.NOZ+1)D(J)=MINF                 QS020620
      DELPSV(I,J)=D(J)                                                  QS020630
C     END                                                               QS020640
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2076  IF(E(J).NE.0.)BOPS=ATAN2(F(J),E(J))*180./PI                      QS020650
      BOPR=-999.                                                        QS020660
      IF(D(J).NE.0.)                                                    QS020670
     1BOPR=2./GAMMA*(DELPHI(J)*(1.-EFFAC)/D(J)/D(J)-1./MINF/MINF)       QS020680
      IF(MINF.LT..25)BOPR=1.+DELPHI(J)*(EFFAC-1.)                       QS020690
      XOCX=(X(I,J)-XLOW)/(XHI-XLOW)                                     QS020700
      FADBOP=(Y(I,J)-YLOW)/(XHI-XLOW)                                   QS020710
      IF(ALLOUT.AND.MM2.EQ.1)                                           QS020720
     1WRITE(6,12) J3M,XOCX,FADBOP,PHI(I,J),E(J),F(J),DELPHI(J)          QS020730
     1,D(J),BOPS,BOPR                                                   QS020740
      TENOLF(I,J)=BOPR                                                  QS020750
C     END                                                               QS020760
1427  CONTINUE                                                          QS020770
12    FORMAT(15X,I4,4X,9F10.5)                                          QS020780
      RETURN                                                            QS020790
      END                                                               QS020800
      SUBROUTINE WRAPUP(ZETA,ETA,S)                                     QS020810
                                                                        QS020820
                                                                        QS020830
C             GEOMETRY GENERATION FOR CASCADE POTENTIAL FLOW SOLVER     QS020840
                                                                        QS020850
                                                                        QS020860
                                                                        QS020870
      LOGICAL DOSURF,SMOOTH,BUG2,ORTHO                                  QS020880
      REAL LAMDAO                                                       QS020890
      COMPLEX H1,H2,ORIGIN,CDWISE                                       QS020900
      COMPLEX AI/(0.,1.)/                                               QS020910
      DOUBLE PRECISION CAPK,CAPKP                                       QS020920
      DIMENSION ZETA(100),ETA(100),DUMBE(100),H1(100),H2(100)           QS020930
      DIMENSION XB(200),YB(200),DUMBX(100,30)                           QS020940
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DUMBY(100,30)     QS020950
      COMMON/GEOM/NOZ,M,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK        QS020960
     1,CAPKP,PI                                                         QS020970
     1,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS                          QS020980
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL               QS020990
      NAMELIST/INSTUF/H1,H2,IMAXY,BUG2                                  QS021000
      DATA ORTHO/.FALSE./,BUG2/.FALSE./                                 QS021010
                                                                        QS021020
      MAGIC=0                                                           QS021030
      MAGICM=0                                                          QS021040
                                                                        QS021050
                                                                        QS021060
      REWIND 18                                                         QS021070
                                                                        QS021080
C      RECORD OLD COMPUTATIONAL VARIABLES FOR INTERPOLATION IN FILPHI   QS021090
                                                                        QS021100
      WRITE(18) ETA,ZETA                                                QS021110
      PI=3.14159265                                                     QS021120
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      SO=CHORD
C      IF(NOZ.LT.0) OBTAIN MESH FROM STORAGE FILE

      IF(NOZ.LE.0) GOTO201
C     IF(NOZ.GT.0) GENERATE A NEW MESH
      IEXIT=2*NOZ-1
      NZZ=IEXIT
      DOSURF=.TRUE.
      IF(NED.LE.0)DOSURF=.FALSE.
      NED=IABS(NED)
      IF(DOSURF)READ(5,INSTUF,END=15)
C     WRITE(6,12)
12    FORMAT(37HTHE FOLLOWING IS THE FIRST ECHO PRINT)
C     WRITE(6,INSTUF)
15    IF(DOSURF)READ(5,INSTUF,END=16)
      WRITE(6,11)
11    FORMAT(38HTHE FOLLOWING IS THE SECOND ECHO PRINT)
      WRITE(6,INSTUF)
16    IF(KN.EQ.0)ORTHO=.TRUE.
      IF(ORTHO) GOTO203
C     IF(.NOT.ORTHO) REARRANGE H2 INPUT INTO H1(UPPER SURFACE), AND H2(L
C     OWER SURFACE)
C      UNSTAGGERED DATA TABLES, FOR THE INTERPOLATION SCHEME

      NEDKN1=NED-KN+1
      ORIGIN=H2(NEDKN1)
      DO 205 I1=1,KN
      I5=NED-KN+I1
      H1(I1)=H2(I5)
      CDWISE =(H1(I1)-ORIGIN)*CEXP(-AI*LAMDA0)
      H1(I1)=CDWISE
205   CONTINUE
      DO 206 I1=1,NEDKN1
      I6=NED-KN-I1+2
      IF(I6.LE.0)I6=1
206   H1(KN+I1)=H2(I6)
      DO 209 I1=1,NEDKN1
      H2(I1)=H1(KN+I1)
      CDWISE=(H2(I1)-ORIGIN)*CEXP(-AI*LAMDA0)
      H2(I1)=CDWISE
209   CONTINUE
      NED=NED+1
      GOTO233

C      IF(ORTHO) REARRANGE H2 INPUT TO START AT MINIMUM Y POINT RATHER T
C     HAN MAX X,
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C      FOR ELECTROSTATIC ANALOG SCHEME                                  QS021610
                                                                        QS021620
203   T2=1.E10                                                          QS021630
      IT2=0                                                             QS021640
      DO 2333 I1=1,NED                                                  QS021650
      IF(AIMAG(H2(I1)).GE.T2) GOTO2333                                  QS021660
      IT2=I1                                                            QS021670
      T2=AIMAG(H2(IT2))                                                 QS021680
2333  CONTINUE                                                          QS021690
      DO 23333 I1=1,NED                                                 QS021700
      I7=IT2+I1-1                                                       QS021710
      IF(I7.EQ.NED)IT3=I1                                               QS021720
      IF(I7.GT.NED)I7=I1-IT3+1                                          QS021730
23333 H1(I1)=H2(I7)                                                     QS021740
      T2=-1.E10                                                         QS021750
      I2T=0                                                             QS021760
      DO 2033 I1=1,NED                                                  QS021770
      IF(AIMAG(H1(I1)).LE.T2)GOTO2033                                   QS021780
      T2=AIMAG(H1(I1))                                                  QS021790
      I2T=I1                                                            QS021800
2033  H2(I1)=H1(I1)                                                     QS021810
                                                                        QS021820
                                                                        QS021830
      IMAXY=I2T                                                         QS021840
                                                                        QS021850
C      LOAD COMPLEX INPUT INTO XBOD AND YBOD ARRAYS                     QS021860
                                                                        QS021870
233   CONTINUE                                                          QS021880
      DO 213 K=1,NED                                                    QS021890
      KMKN=K-KN                                                         QS021900
      IF(K.GT.KN) GOTO217                                               QS021910
C     IF(K.LE.KN) THEN                                                  QS021920
      XB(K)=REAL(H1(K))                                                 QS021930
      YB(K)=AIMAG(H1(K))                                                QS021940
      GOTO213                                                           QS021950
217   XB(K)=REAL(H2(KMKN))                                              QS021960
      YB(K)=AIMAG(H2(KMKN))                                             QS021970
213   CONTINUE                                                          QS021980
      IF(CHORD.EQ.1.) GOTO219                                           QS021990
C     IF(CHORD.NE.1.) NORMALIZE COORDINATES TO AERODYNAMIC CHORD        QS022000
      DO 221 I2=1,NED                                                   QS022010
      XB(I2)=XB(I2)/CHORD                                               QS022020
221   YB(I2)=YB(I2)/CHORD                                               QS022030
      RLE=RLE/CHORD                                                     QS022040
      RTE=RTE/CHORD                                                     QS022050
      S=S/CHORD                                                         QS022060
      CHORD=1.                                                          QS022070
C     END                                                               QS022080
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                                                                        QS022090
                                                                        QS022100
                                                                        QS022110
219   IF(.NOT.ORTHO) GOTO225                                            QS022120
C     IF(ORTHO) DO ELECTROSTATIC ANALOG GRID                            QS022130
                                                                        QS022140
      DO 227 I2=1,NED                                                   QS022150
227   H1(I2)=CMPLX(XB(I2),YB(I2))                                       QS022160
      WRITE(6,9)                                                        QS022170
9     FORMAT(1H1,40X,' ELECTROSTATIC ANALOG GRID GENERATED')            QS022180
      CALL PJGRID(ZETA,ETA,H1,IMAXY,S)                                  QS022190
      GOTO226                                                           QS022200
                                                                        QS022210
                                                                        QS022220
C      OTHERWISE DO INTERPOLATION SCHEME GRID                           QS022230
                                                                        QS022240
225   WRITE(6,10)                                                       QS022250
10    FORMAT(1H1,40X,' INTERPOLATION SCHEME GRID GENERATED')            QS022260
      CALL GRIDDL(ZETA,ETA,XB,YB,S)                                     QS022270
                                                                        QS022280
C      WRITE MESH POINTS STORAGE FILE                                   QS022290
                                                                        QS022300
226   WRITE(13,1) NOZ,M,KN,NED                                          QS022310
      WRITE(13,2)((X(I,J),I=1,NZZ),J=1,M),((Y(I,J),I=1,NZZ),J=1,M)     QS022320
     1,(ETA(I),I=1,NZZ),(ZETA(J),J=1,M)                                 QS022330
                                                                        QS022340
                                                                        QS022350
                                                                        QS022360
      GOTO202                                                           QS022370
                                                                        QS022380
                                                                        QS022390
C      FOR EXISTING MESH FILES, NORMALIZE PARAMETERS AND READ FILE      QS022400
                                                                        QS022410
201   IF(CHORD.EQ.1.) GOTO231                                           QS022420
C     IF(CHORD.NE.1.) THEN                                              QS022430
      RLE=RLE/CHORD                                                     QS022440
      PTE=RTE/CHORD                                                     QS022450
      S=S/CHORD                                                         QS022460
      CHORD=1.                                                          QS022470
C     END                                                               QS022480
231   READ(23,1) NOZZ,MM,KN,NED                                         QS022490
      MAGIC=IABS((NOZZ-1)/(NOZ+1))                                      QS022500
      MAGICM=(MM-1)/(M-1)                                               QS022510
      M=MM                                                              QS022520
      NOZ=NOZZ                                                          QS022530
      IEXIT=2*NOZ-1                                                     QS022540
      NZZ=IEXIT                                                         QS022550
      READ(23,2)((X(I,J),I=1,NZZ),J=1,M),((Y(I,J),I=1,NZZ),J=1,M)      QS022560
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     1,(ETA(I),I=1,NZZ),(ZETA(J),J=1,M)                                 QS022570
                                                                        QS022580
C      IF FINEST MESH IS DESIRED, SKIP SELECTION PROCESS                QS022590
                                                                        QS022600
      IF(MAGIC.LE.1.AND.MAGICM.LE.1) GOTO202                            QS022610
C     IF(MAGIC.GT.1.OR.MAGICM.GT.1) SELECT AND LOAD GRID LINES DESIRED TQS022620
C     O FORM                                                            QS022630
C      A COARSE MESH                                                    QS022640
      DO 235 J=1,M,MAGICM                                               QS022650
      JON=(J-1)/MAGICM+1                                                QS022660
      ZETA(JON)=ZETA(J)                                                 QS022670
      DO 239 I=1,NZZ,MAGIC                                              QS022680
      ION=(I-1)/MAGIC+1                                                 QS022690
      DUMBX(ION,JON)=X(I,J)                                             QS022700
  239 DUMBY(ION,JON)=Y(I,J)                                             QS022710
      IF(MOD(ION,2).EQ.0) ION=ION-1                                     QS022720
                                                                        QS022730
C      RADIATING LINE TO UPSTREAM INFINITY MUST BE INCLUDED             QS022740
      DUMBX(ION,JON)=X(NZZ,J)                                           QS022750
      DUMBY(ION,JON)=Y(NZZ,J)                                           QS022760
                                                                        QS022770
      NOZZ=(ION+1)/2                                                    QS022780
                                                                        QS022790
C      RADIATING LINE TO DOWNSTREAM INFINITY MUST BE INCLUDED           QS022800
      DUMBX(NOZZ,JON)=X(NOZ,J)                                          QS022810
  235 DUMBY(NOZZ,JON)=Y(NOZ,J)                                          QS022820
                                                                        QS022830
      DO 243 I=1,ION                                                    QS022840
      IOLD=(I-1)*MAGIC+1                                                QS022850
      ETA(I)=ETA(IOLD)                                                  QS022860
                                                                        QS022870
C      BLADE SURFACE MUST BE LAST CLOSED CURVE                          QS022880
      DUMBX(I,JON)=X(IOLD,M)                                            QS022890
      DUMBY(I,JON)=Y(IOLD,M)                                            QS022900
                                                                        QS022910
C      PERIODIC BOUNDARY MUST BE FIRST CLOSED CURVE                     QS022920
      DUMBX(I,1)=X(IOLD,1)                                              QS022930
  243 DUMBY(I,1)=Y(IOLD,1)                                              QS022940
                                                                        QS022950
      DUMBX(ION,JON)=X(NZZ,M)                                           QS022960
      DUMBY(ION,JON)=Y(NZZ,M)                                           QS022970
      DUMBX(ION,1)=X(NZZ,1)                                             QS022980
      DUMBY(ION,1)=Y(NZZ,1)                                             QS022990
      DUMBX(NOZZ,M)=X(NOZ,M)                                            QS023000
      DUMBY(NOZZ,M)=Y(NOZ,M)                                            QS023010
      DUMBY(NOZZ,1)=Y(NOZ,1)                                            QS023020
      DUMBX(NOZZ,1)=X(NOZ,1)                                            QS023030
                                                                        QS023040
```

```

      DO 251 J=1,JON
      DO 251 I=1,ION
      X(I,J)=DUMBX(I,J)
  251 Y(I,J)=DUMBY(I,J)
      ZETA(JON)=ZETA(M)
      ETA(ION)=ETA(NZZ)
      ETA(NOZZ)=ETA(NOZ)
      NZZ=ION
      IEXIT=NZZ
      NOZ=NOZZ
      M=JON

C       END OF SELECTION PROCESS

  202 CONTINUE
      IF(.NOT.BUG2) GOTO255

C     IF(BUG2) THEN
      WRITE( 6,3) NOZ,M,KN,NED
    3 FORMAT('ONOZ= ',I3,' M= ',I3,' KN= ',I3,' NED= ',I3)
      NEDM1=NED-1


C       FOR A NEW GEOMETRY GENERATION, CALCULATE THE SECOND DERIVATIVES O
C     N BLADE
C       SURFACE USING SMOOTHED INPUT COORDINATES

      DO 257 I=2,NEDM1
      DUMBX(I,15)=1.E06
      IF(XB(I).NE.XB(I-1).AND.XB(I).NE.XB(I+1).AND.
     1XB(I+1).NE.XB(I-1))
     1DUMBX(I,15)=((YB(I+1)-YB(I))/(XB(I+1)-XB(I))-(YB(I)-YB(I-1))/
     1(XB(I)-XB(I-1)))/(XB(I+1)-XB(I-1))*2.
  257 CONTINUE


      WRITE(6,5)
      WRITE(6,55)
    5 FORMAT(1H0,35X,'SMOOTHED BLADE SURFACE INPUT, HORIZONTAL CHORD')
   55 FORMAT(1H0,35X,'  I       X          Y           2ND DERIV.   '/)
    6 FORMAT(1H0,20X,'X GRID POINTS, AS STORED ON MESH FILE'/)
    7 FORMAT(1H0,20X,'Y GRID POINTS, AS STORED ON MESH FILE'/)
    4 FORMAT(35X,I4,3E13.5)
      WRITE(6,4) (I,XB(I),YB(I),DUMBX(I,15),I=1,NED)
      WRITE(6,6)
      WRITE(6,2)((X(I,J),I=1,NZZ),J=1,M)
      WRITE(6,7)
```

```
      WRITE(6,2) ((Y(I,J),I=1,NZZ),J=1,M)                              QS023530
1     FORMAT(4I5)                                                       QS023540
14    FORMAT(1H ,14E9.3)                                                QS023550
2     FORMAT(6E13.5)                                                    QS023560
                                                                        QS023570
                                                                        QS023580
                                                                        QS023590
255   IF(KN.NE.0)GOTO 261                                               QS023600
C     IF(ORTHO) TRANSLATE THE ORIGIN OF X POINTS TO MIDCHORD (INTERP SCHQS023610
C     EME                                                               QS023620
C      ALREADY TRANSLATED                                               QS023630
                                                                        QS023640
      DO 263 I1=1,NZZ                                                   QS023650
      DO 263 J1=1,M                                                     QS023660
263   X(I1,J1)=X(I1,J1)-.5                                              QS023670
                                                                        QS023680
C      REARRANGE (X,Y) TABLES SO THAT X(2,J),Y(2,J) AND X(NZZ+1,J),Y(NZZQS023690
C     +1,J) GO                                                          QS023700
C      TO DOWNSTREAM INFINITY, AND X(NOZ+1,J),Y(NOZ+1,J) GOES TO UPSTREAQS023710
C     M INFINITY                                                        QS023720
C      NUMBERING THE LINES CLOCKWISE AROUND THE BLADE.  AT PRESENT, LINEQS023730
C      1 GOES                                                           QS023740
C      TO UPS. INF.,  NOZ GOES TO DOWNS. INF. AND NZZ TO UPS. INF.      QS023750
C                                                                       QS023760
C      ALSO REALIGN ETA SO THAT VALUES WILL GO FROM ZERO (LINE 2) TO 2*CQS023770
C     APKP (LINE                                                        QS023780
C      NZZ+1), INSTEAD OF -CAPKP (LINE 1)  TO +CAPKP (LINE NZZ).        QS023790
                                                                        QS023800
261   DO 271 I1=1,NOZ                                                   QS023810
      DO 271 J1=1,M                                                     QS023820
      I2=I1+NOZ-1                                                       QS023830
      DUMBE(I1)=-ETA(I2)                                                QS023840
      DUMBX(I1,J1)=X(I1,J1)                                             QS023850
      DUMBY(I1,J1)=Y(I1,J1)                                             QS023860
      X(I1,J1)=X(I1+NOZ-1,J1)                                           QS023870
271   Y(I1,J1)=Y(I1+NOZ-1,J1)                                           QS023880
      NOZP1=NOZ+1                                                       QS023890
      DO 279 I1=NOZP1,NZZ                                               QS023900
      DO 279 J1=1,M                                                     QS023910
      I2=I1-NOZ+1                                                       QS023920
      DUMBE(I1)=-ETA(I2)+2.*ETA(1)                                      QS023930
      DUMBX(I1,J1)=X(I1,J1)                                             QS023940
      DUMBY(I1,J1)=Y(I1,J1)                                             QS023950
      X(I1,J1)=DUMBX(I1-NOZ+1,J1)                                       QS023960
279   Y(I1,J1)=DUMBY(I1-NOZ+1,J1)                                       QS023970
                                                                        QS023980
C      MOVE ALL VALUES UP 3 LOCATIONS IN J TO MAKE ROOM FOR 3 DUMMY ELLIQS023990
C     PSES                                                              QS024000
```

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C       BEYOND THE PERIODIC LINE.                                       QS024010
                                                                        QS024020
      I1=IEXIT                                                          QS024030
2088  IF(I1.LT.1)GOTO2872                                               QS024040
2955  J1=M                                                              QS024050
2087  IF(J1.LT.1)GOTO2871                                               QS024060
      X(I1,J1+3)= X(I1,J1)                                              QS024070
      IF(I1.EQ.1)ZETA(J1+3)=ZETA(J1)                                    QS024080
287   Y(I1,J1+3)= Y(I1,J1)                                              QS024090
      J1=J1-1                                                           QS024100
      GOTO2087                                                          QS024110
2871  I1=I1-1                                                           QS024120
      GOTO2088                                                          QS024130
                                                                        QS024140
                                                                        QS024150
C       FINISH LOADING ETA; CREATE 3 DUMMY LINES USING PERIODIC RELATIONQS024160
C     OF X,Y VALUES                                                     QS024170
                                                                        QS024180
2872  I1=IEXIT                                                          QS024190
295   IF(I1.LT.2)GOTO2951                                               QS024200
      ETA(I1)=DUMBE(I1)                                                 QS024210
      DO 299 J1=1,3                                                     QS024220
      SIGEN=1.                                                          QS024230
      IF(I1.LT.NOZ)SIGEN=-1.                                            QS024240
      IF(I1.EQ.NOZ)SIGEN=0.                                             QS024250
      X(I1,J1)=X(IEXIT-I1+1 ,8-J1)+S*SIN(LAMDAO) *SIGEN                 QS024260
      IF(I1.EQ.2)ZETA(J1)=-ZETA(8-J1)                                   QS024270
299   Y(I1,J1)=Y(IEXIT-I1+1 ,8-J1)+S*COS(LAMDAO)*SIGEN                  QS024280
      ETA(I1+1)=ETA(I1)                                                 QS024290
                                                                        QS024300
                                                                        QS024310
C       LOAD SPECIAL POINTS (J=4 NOW EQUALS PERIODIC LINE POINTS)       QS024320
                                                                        QS024330
      I1=I1-1                                                           QS024340
      GOTO 295                                                          QS024350
2951  ETA(2)=0.                                                         QS024360
      ETA(IEXIT+1)=2.*ETA(1)                                            QS024370
      X(IEXIT,1)=2.*X(IEXIT,4)                                          QS024380
      X(IEXIT,2)=1.5*X(IEXIT,4)                                         QS024390
      X(IEXIT,3)=1.2*X(IEXIT,4)                                         QS024400
      Y(IEXIT,1)=2.*Y(IEXIT,4)                                          QS024410
      Y(IEXIT,2)=1.5*Y(IEXIT,4)                                         QS024420
      Y(IEXIT,3)=1.2*Y(IEXIT,4)                                         QS024430
      X(NOZ,1)=2.*X(NOZ,4)                                              QS024440
      X(NOZ,2)=1.5*X(NOZ,4)                                             QS024450
      X(NOZ,3)=1.2*X(NOZ,4)                                             QS024460
      Y(NOZ,1)=2.*Y(NOZ,4)                                              QS024470
      Y(NOZ,2)=1.5*Y(NOZ,4)                                             QS024480
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      Y(NOZ,3)=1.2*Y(NOZ,4)                                             QS024490
      MP3=M+3                                                           QS024500
                                                                        QS024510
C      MOVE ALL DATA UP ONE I LOCATION TO MAKE ROOM FOR A REPEATED RADIAQS024520
C     TING LINE                                                         QS024530
C      NEXT TO DOWNSTREAM INFINITY LINE .                               QS024540
                                                                        QS024550
      DO 2103 J1=1,MP3                                                  QS024560
      I1=IEXIT                                                          QS024570
2107  IF(I1.LT.1)GOTO21071                                              QS024580
      X(I1+1, J1)=X(I1,J1)                                              QS024590
      Y(I1+1, J1)=Y(I1,J1)                                              QS024600
      DUMBX(I1,J1)=0.                                                   QS024610
      DUMBY(I1,J1)=0.                                                   QS024620
      I1=I1-1                                                           QS024630
      GOTO2107                                                          QS024640
21071 X(2,J1)=X(IEXIT+1,J1)                                             QS024650
      Y(2,J1)=Y(IEXIT+1,J1)                                             QS024660
      X(1,J1)=X(IEXIT  ,J1)                                             QS024670
      Y(1,J1)=Y(IEXIT  ,J1)                                             QS024680
      X(IEXIT+2,J1)=X(3,J1)                                             QS024690
2103  Y(IEXIT+2,J1)=Y(3,J1)                                             QS024700
                                                                        QS024710
                                                                        QS024720
      ETA(IEXIT+2)=ETA(3)+2.*ETA(1)                                     QS024730
      ETA(1)=-ETA(3)                                                    QS024740
                                                                        QS024750
C      UPDATE COUNTERS                                                  QS024760
                                                                        QS024770
      NZZ=NZZ+1                                                         QS024780
      IEXIT=IEXIT+1                                                     QS024790
      NOZ=NOZ+1                                                         QS024800
      M=M+3                                                             QS024810
                                                                        QS024820
                                                                        QS024830
      ZETA(M+1)=ZETA(M)+ZETA(M)-ZETA(M-1)                               QS024840
      I67=M-14+1                                                        QS024850
      I67=MAX0(I67,1)                                                   QS024860
      I671=I67+1                                                        QS024870
                                                                        QS024880
                                                                        QS024890
                                                                        QS024900
      IF(.NOT.BUG2) RETURN                                              QS024910
                                                                        QS024920
                                                                        QS024930
C      FOR NEW GEOMETRY GENERATIONS, CALCULATE SECOND DERIVATIVES ON BLAQS024940
C     DE SURFACE                                                        QS024950
C      USING THE FINAL GRID POINTS.                                     QS024960
```

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                                                                        QS024970
      NZZM1=NZZ-1                                                       QS024980
      DO 2113 I=2,NZZM1                                                 QS024990
      DUMBX(I,15)=1.E06                                                 QS025000
      IF(X(I,M).NE.X(I-1,M).AND.X(I,M).NE.X(I+1,M).AND.                 QS025010
     1X(I+1,M).NE.X(I-1,M))DUMBX(I,15)=                                 QS025020
     1((Y(I+1,M)-Y(I,M))/(X(I+1,M)-X(I,M))-(Y(I,M)-Y(I-1,M))/           QS025030
     1(X(I,M)-X(I-1,M)))/(X(I+1,M)-X(I-1,M))*2.                         QS025040
2113  CONTINUE                                                          QS025050
                                                                        QS025060
                                                                        QS025070
      WRITE(6,8)                                                        QS025080
8     FORMAT(1H0,30X,' GRID OUTPUT POINTS ON BLADE SURFACE, ',          QS025090
     1'HORIZONTAL CHORD'//36X'  I      X           Y',                  QS025100
     1'         2ND DERIV.  '/)                                         QS025110
      DO 2119 I=2,NZZM1                                                 QS025120
      I1M=I-1                                                           QS025130
2119  WRITE(6,4) I1M,X(I,M),Y(I,M),DUMBX(I,15)                          QS025140
      BUG2=.FALSE.                                                      QS025150
                                                                        QS025160
                                                                        QS025170
                                                                        QS025180
                                                                        QS025190
      RETURN                                                            QS025200
      END                                                               QS025210
      SUBROUTINE GRIDDL(ET,ZET,XBOD,YBOD,S)                             QS025220
                                                                        QS025230
                                                                        QS025240
C                    INTERPOLATION SCHEME GRID GENERATOR                QS025250
                                                                        QS025260
                                                                        QS025270
                                                                        QS025280
C      IF(STAG.NE.O) DO (INTERMEDIATE TRANSFORM SETUP, ZERO STAG, S=2PI)QS025290
C      DO (CALCULATION OF GEOMETRY CONSTANTS)                           QS025300
C      DO (KNOWN GRID COORDINATES, ET, ZET)                             QS025310
C            IF(SLP2.LT.0) THEN                                         QS025320
C                   DO (FLATPLATE-ZERO STAGGER TRANSFORM, UPPER SURFACE)QS025330
C                   DO (FLATPLATE-ZERO STAGGER TRANSFORM, LOWER SURFACE)QS025340
C                   CALL TOSTAG(S,ZET,CHORD)                            QS025350
C            DO (CONCENTRATION OF RADIATING LINES, ZET)                 QS025360
C            DO (CONCENTRATION OF SURFACE CONTOURS, ET)                 QS025370
C      DO (FLATPLATE-ZERO STAGGER TRANSFORM, UPPER SURFACE)             QS025380
C      DO (FLATPLATE-ZERO STAGGER TRANSFORM, LOWER SURFACE)             QS025390
C      DO (SPECIAL POINTS)                                              QS025400
C      DO (CIRCLE TRANSFM. FROM ZERO STAGGER TO INPUT VALUES)           QS025410
C      DO (RECALCULATION OF GEOMETRY CONSTANTS)                         QS025420
C      DO (TRANSLATE ORIGIN OF INPUT BODY POINTS TO MIDCHORD)           QS025430
C      DO (TRAILING EDGE FIX OF EXTRA CAMBER POINTS)                    QS025440
```

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C       DO (ADDITION OF BLADE SURFACE ON CLEAN FLATPLATE MESH)                  QS025450
C       RETURN                                                                  QS025460
                                                                                QS025470
                                                                                QS025480
                                                                                QS025490
                                                                                QS025500
      DIMENSION  ET(100),ZET(100),XBOD(200)    ,YBOD(200)                       QS025510
      REAL  K,LNK,M1,LAM,LAMDA0,M                                               QS025520
      INTEGER ZNO,ENO,ZN2M1,ZN2,END,ENOPLS,CAMBER,ZNP1,ENOP1                    QS025530
      DOUBLE PRECISION MMDELK                                                   QS025540
      DOUBLE PRECISION  CAPK,CAPKP,DM,DM1                                       QS025550
      LOGICAL DOSURF,SMOOTH                                                     QS025560
      COMMON/ENTIRE/  X(100,30),Y(100,30)                                       QS025570
      COMMON/GEOM/ZNO,ENO,RLE,RTE,A,CHORB,XUPS,XDNS,STAG,CC,CAPK                QS025580
     1,CAPKP,PI                                                                 QS025590
     1,LNK,M1,KM,END,M,DOSURF,R,SOLID,ENOPLS                                    QS025600
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,DUMBO(5),CAMBER                        QS025610
      XUPS=-1.E+01                                                              QS025620
      XDNS=1.E+01                                                               QS025630
      PI=3.14159265                                                             QS025640
      DELTA=0.                                                                  QS025650
      ZNP1=ZNO+1                                                                QS025660
      LAMDA0=STAG                                                               QS025670
555   FORMAT(1H ,2E12.5)                                                        QS025680
      ENOPLS=ENO+ENO/CAMBER                                                     QS025690
      CHORD=CHORB-RLE/2.-RTE/2.                                                 QS025700
      XDNS= 25.*CHORD                                                           QS025710
      XUPS=-25.*CHORD                                                           QS025720
      SOLID=CHORB/S                                                             QS025730
      SOLFLT=CHORD/S                                                            QS025740
      SOLID0=SOLFLT                                                             QS025750
      IF(STAG.EQ.0.)GOTO3002                                                    QS025760
                                                                                QS025770
                                                                                QS025780
C     DO (INTERMEDIATE TRANSFORM SETUP, I.E. ZERO STAG, S=2PI)                  QS025790
                                                                                QS025800
C     PROCEDURE (INTERMEDIATE TRANSFORM SETUP, I.E. ZERO STAG, S=2PI)           QS025810
      ASTAG=ABS(STAG)                                                           QS025820
      CALL ALTERP(SOLFLT,ASTAG,ALFA,R)                                          QS025830
      CHORD=ALOG((R*R+2.*R+1.)/(R*R-2.*R+1.))*2.                                QS025840
      SOLID0=CHORD/PI/2.                                                        QS025850
      S=2.*PI                                                                   QS025860
      LAMDA0=0.                                                                 QS025870
C     END                                                                       QS025880
                                                                                QS025890
3002  CONTINUE                                                                  QS025900
                                                                                QS025910
                                                                                QS025920
```

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C     DO (CALCULATION OF GEOMETRY CONSTANTS)                            QS025930
                                                                        QS025940
C     PROCEDURE (CALCULATION OF GEOMETRY CONSTANTS)                     QS025950
      A= COS(LAMDAO)/2./SOLIDO                                          QS025960
      K= EXP(-PI/2./A)                                                  QS025970
      LNK = -ALOG(K)                                                    QS025980
      M=K*K                                                             QS025990
      DM=M                                                              QS026000
      DM1=1.DO-DM                                                       QS026010
      M1=DM1                                                            QS026020
      CAPK=MMDELK(1,DM,IER)                                             QS026030
      CAPKP=MMDELK(1,DM1,IER)                                           QS026040
C     END                                                               QS026050
                                                                        QS026060
                                                                        QS026070
                                                                        QS026080
C     DO (KNOWN GRID COORDINATES, ET,ZET)                               QS026090
                                                                        QS026100
C     PROCEDURE (KNOWN GRID COORDINATES, ET,ZET)                        QS026110
      DELZ=CAPKP/(ZNO-1)                                                QS026120
      DELE=CAPK*STABAC/(ENO-1)                                          QS026130
      ZN2M1=2*ZNO-1                                                     QS026140
      ZET(1)=+CAPKP                                                     QS026150
      DO 217  NZ=2,ZN2M1                                                QS026160
217   ZET(NZ)=ZET(NZ-1)-DELZ                                            QS026170
      ET(1)=0.                                                          QS026180
      ZN2 =  2*ZNO                                                      QS026190
      DO 221  NE=2,ENOPLS                                               QS026200
221   ET(NE)=ET(NE-1)+DELE                                              QS026210
      ET(ENO)=STABAC*CAPK                                               QS026220
      ZET(ZNO)=0.                                                       QS026230
      IF(SLP1.GE.0.)GOTO205                                             QS026240
                                                                        QS026250
                                                                        QS026260
C     IF(SLP1.LT.0.) DO (CONCENTRATION OF GRID LINES IN KEY AREAS)      QS026270
C     PROCEDURE (CONCENTRATION OF GRID LINES IN KEY AREAS)              QS026280
      XTES=-1.E19                                                       QS026290
      ITS=1                                                             QS026300
      SLP1=-SLP1                                                        QS026310
                                                                        QS026320
                                                                        QS026330
C      IF SLP2.LT.0 SETUP THE PROPER STAGGERED FLATPLATE MESH TO FIND WHQS026340
C     ICH LINE                                                          QS026350
C      INTERSECTS T. E.                                                 QS026360
                                                                        QS026370
                                                                        QS026380
      IF(SLP2.GE.0..OR.S.NE.2.*PI) GOTO226                              QS026390
      DELTA=ABS(SLP2)                                                   QS026400
```

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C       DO (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y UPPER SURFACE)
C       PROCEDURE (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y UPPER SURFACE)
        DO 2060 I=1,ZNO
        DO 2060 J=1,ENOPLS
        IF((I.EQ.1.OR.I.EQ.ZNO).AND.J.EQ.1) GOTO2060
        ETER=ET(J)

C       DO (YOUR BASIC TRANSFORMATION )
C       PROCEDURE (YOUR BASIC TRANSFORMATION )
        ZED=ZET(I)
        IF(ETER.GT.CAPK)ZED=-ZED
        IF(ETER.GT.CAPK) ETER=2.*CAPK-ETER
        IF(I.EQ.ZNO)ZED=0.
        ALLFNC=FUDS(ETER, ZED,M1)
        LAM  = BADZAC(M1)
        TH   = OWOW(M1)
        X(I,J)= CHORD*A/PI*(LNK-2.*ALOG(ALLFNC/LAM))
        IF(J.GT.ENO.AND.I.EQ.ZN2M1)X(I,J)=-CHORD-X(I,J)
        IF(J.GT.ENO.AND.I.EQ.ZNO)X(I,J)=CHORD-X(I,J)
        Y(I,J)= 2.*A*CHORD/PI*TH
        IF(X(I,J).GT.XDNS)X(I,J)=XDNS
        IF(X(I,J).LT.XUPS)X(I,J)=XUPS
C       END

2060    CONTINUE
C       END

C       DO (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y LOWER SURFACE)
C       PROCEDURE (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y LOWER SURFACE)
        DO 2071 I=ZNP1,ZN2M1
        IDIF=I-ZNO
        X(I,1)=X(ZNO-IDIF,1)-S*SIN(LAMDAO)
        Y(I,1)= -A*CHORD
        DO 2071 J=1,ENOPLS
        IF(I.EQ.ZN2M1.AND.J.EQ.1) GOTO2071
        ETER=ET(J)

C       DO (YOUR BASIC TRANSFORMATION )
C       PROCEDURE (YOUR BASIC TRANSFORMATION )
        ZED=ZET(I)
        IF(ETER.GT.CAPK)ZED=-ZED
        IF(ETER.GT.CAPK) ETER=2.*CAPK-ETER
        IF(I.EQ.ZNO)ZED=0.
        ALLFNC=FUDS(ETER, ZED,M1)
        LAM  = BADZAC(M1)
        TH   = OWOW(M1)
        X(I,J)= CHORD*A/PI*(LNK-2.*ALOG(ALLFNC/LAM))
```

```
      IF(J.GT.ENO.AND.I.EQ.ZN2M1)X(I,J)=-CHORD-X(I,J)                 QS026890
      IF(J.GT.ENO.AND.I.EQ.ZNO)X(I,J)=CHORD-X(I,J)                    QS026900
      Y(I,J)= 2.*A*CHORD/PI*TH                                        QS026910
      IF(X(I,J).GT.XDNS)X(I,J)=XDNS                                   QS026920
      IF(X(I,J).LT.XUPS)X(I,J)=XUPS                                   QS026930
C     END                                                             QS026940
                                                                      QS026950
2071  CONTINUE                                                        QS026960
C     END                                                             QS026970
                                                                      QS026980
      CALL TOSTAG(S,ZET,CHORD)                                        QS026990
      DO 234 I3=1,ZN2M1                                               QS027000
      IF(X(I3,ENO).LE.XTES) GOTO234                                   QS027010
C     WRITE(6,4445) XTES,I3,X(I3,ENO)                                 QS027020
4445  FORMAT(E13.5,I6,E13.5)                                          QS027030
      XTES=X(I3,ENO)                                                  QS027040
      ITS=I3                                                          QS027050
234   CONTINUE                                                        QS027060
      EF=ZET(ITS)/CAPKP                                               QS027070
      IF(SLP1.EQ.10.) EF=1.-EF                                        QS027080
      SLP1=(1.-DELTA/EF/EF*(.6667-.2/EF/EF))/                         QS027090
     1(1.-1./EF/EF*(.6667-.2/EF/EF))                                  QS027100
      SLP2=3.-SLP1*(2.-1./2.5/EF**4)-DELTA/2.5/EF**4                  QS027110
226   CONTINUE                                                        QS027120
                                                                      QS027130
                                                                      QS027140
C      CONCENTRATE THE RADIATING LINES  (COMPUTATIONAL COORD ZET)     QS027150
                                                                      QS027160
C     DO (CONCENTRATION POLYNOMIAL)                                   QS027170
C     PROCEDURE (CONCENTRATION POLYNOMIAL)                            QS027180
      CON1=2.5*(1.-SLP1)/CAPKP**2                                     QS027190
      CON2=(SLP2-SLP1)/(2.*CAPKP**2)                                  QS027200
      CON1=CON1-CON2                                                  QS027210
      CON3=(SLP2-SLP1)/(2.*CAPKP**4)                                  QS027220
      CON4=1.5*(1.-SLP1)/(CAPKP**4)                                   QS027230
      CON3=CON3-CON4                                                  QS027240
C     END                                                             QS027250
                                                                      QS027260
      DO 237 I3=1,ZN2M1                                               QS027270
      CAPFAC=0.                                                       QS027280
      ZETER1=ZET(I3)                                                  QS027290
237   ZET(I3)=SLP1*ZETER1+CON1*ZETER1**3+CON3*ZETER1**5-CAPFAC        QS027300
      IF(DELTA.EQ.0.) GOTO241                                         QS027310
      EF=1.-EF                                                        QS027320
      SLP1=(1.-DELTA/EF/EF*(.6667-.2/EF/EF))/                         QS027330
     1(1.-1./EF/EF*(.6667-.2/EF/EF))                                  QS027340
      SLP2=3.-SLP1*(2.-1./2.5/EF**4)-DELTA/2.5/EF**4                  QS027350
                                                                      QS027360
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C     DO (CONCENTRATION POLYNOMIAL)                                     QS027370
C     PROCEDURE (CONCENTRATION POLYNOMIAL)                              QS027380
      CON1=2.5*(1.-SLP1)/CAPKP**2                                       QS027390
      CON2=(SLP2-SLP1)/(2.*CAPKP**2)                                    QS027400
      CON1=CON1-CON2                                                    QS027410
      CON3=(SLP2-SLP1)/(2.*CAPKP**4)                                    QS027420
      CON4=1.5*(1.-SLP1)/(CAPKP**4)                                     QS027430
      CON3=CON3-CON4                                                    QS027440
C     END                                                               QS027450
                                                                        QS027460
                                                                        QS027470
C      CONCENTRATE THE SURFACE CONTOURS (COMPUTATIONAL COORD ET)        QS027480
                                                                        QS027490
      DO 244 I3=1,ZN2M1                                                 QS027500
      CAPFAC=0.                                                         QS027510
      ZETER1=ZET(I3)                                                    QS027520
244   ZET(I3)=SLP1*ZETER1+CON1*ZETER1**3+CON3*ZETER1**5-CAPFAC          QS027530
241   CON5=2.5*(1.-SLP3)/CAPK**2                                        QS027540
      CON6=(SLP4-SLP3)/(2.*CAPK**2)                                     QS027550
      CON5=CON5-CON6                                                    QS027560
      CON7=(SLP4-SLP3)/2/CAPK**4                                        QS027570
      CON8=1.5*(1.-SLP3)/CAPK**4                                        QS027580
      CON7=CON7-CON8                                                    QS027590
      DO 248 J3=1,ENOPLS                                                QS027600
      IF(J3.GT.ENO)ET(J3)=2.*CAPK-ET(J3)                                QS027610
      ET(J3)=SLP3*ET(J3)+CON5*ET(J3)**3+CON7*ET(J3)**5                  QS027620
      IF(J3.GT.ENO)ET(J3)=2.*CAPK-ET(J3)                                QS027630
248   CONTINUE                                                          QS027640
      SLP1=-SLP1                                                        QS027650
      IF(DELTA.NE.0.)SLP2=-DELTA                                        QS027660
4446  FORMAT(6E13.5)                                                    QS027670
C     END                                                               QS027680
                                                                        QS027690
                                                                        QS027700
                                                                        QS027710
                                                                        QS027720
C     END OF CONCENTRATION PROCEDURE                                    QS027730
                                                                        QS027740
                                                                        QS027750
                                                                        QS027760
205   X(1,1)=XUPS                                                       QS027770
      X(ZNO,1)=XDNS                                                     QS027780
      X(ZN2M1,1)=XUPS                                                   QS027790
      NZNOM1=ZNO-1                                                      QS027800
                                                                        QS027810
                                                                        QS027820
C     DO (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y UPPER SURFACE)        QS027830
                                                                        QS027840
```

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C     PROCEDURE (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y UPPER SURFACE) QS027850
      DO 260 I=1,ZNO                                                    QS027860
      DO 260 J=1,ENOPLS                                                 QS027870
      IF((I.EQ.1.OR.I.EQ.ZNO).AND.J.EQ.1) GOTO260                       QS027880
      ETER=ET(J)                                                        QS027890
                                                                        QS027900
                                                                        QS027910
C     DO (YOUR BASIC TRANSFORMATION )                                   QS027920
C     PROCEDURE (YOUR BASIC TRANSFORMATION )                            QS027930
      ZED=ZET(I)                                                        QS027940
      IF(ETER.GT.CAPK)ZED=-ZED                                          QS027950
      IF(ETER.GT.CAPK) ETER=2.*CAPK-ETER                                QS027960
      IF(I.EQ.ZNO)ZED=0.                                                QS027970
      ALLFNC=FUDS(ETER, ZED,M1)                                         QS027980
      LAM   = BADZAC(M1)                                                QS027990
      TH    = OWOW(M1)                                                  QS028000
      X(I,J)= CHORD*A/PI*(LNK-2.*ALOG(ALLFNC/LAM))                       QS028010
      IF(J.GT.ENO.AND.I.EQ.ZN2M1)X(I,J)=-CHORD-X(I,J)                   QS028020
      IF(J.GT.ENO.AND.I.EQ.ZNO)X(I,J)=CHORD-X(I,J)                      QS028030
      Y(I,J)= 2.*A*CHORD/PI*TH                                          QS028040
      IF(X(I,J).GT.XDNS)X(I,J)=XDNS                                     QS028050
      IF(X(I,J).LT.XUPS)X(I,J)=XUPS                                     QS028060
C     END                                                               QS028070
                                                                        QS028080
260   CONTINUE                                                          QS028090
C     END                                                               QS028100
                                                                        QS028110
      ZNP1=ZNO+1                                                        QS028120
      FK=1./SQRT(K)                                                     QS028130
      NZN2M2=ZN2M1-1                                                    QS028140
                                                                        QS028150
                                                                        QS028160
C     DO (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y LOWER SURFACE)        QS028170
                                                                        QS028180
C     PROCEDURE (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y LOWER SURFACE) QS028190
      DO 271 I=ZNP1,ZN2M1                                               QS028200
      IDIF=I-ZNO                                                        QS028210
      X(I,1)=X(ZNO-IDIF,1)-S*SIN(LAMDAO)                                QS028220
      Y(I,1)= -A*CHORD                                                  QS028230
      DO 271 J=1,ENOPLS                                                 QS028240
      IF(I.EQ.ZN2M1.AND.J.EQ.1) GOTO271                                 QS028250
      ETER=ET(J)                                                        QS028260
                                                                        QS028270
C     DO (YOUR BASIC TRANSFORMATION )                                   QS028280
C     PROCEDURE (YOUR BASIC TRANSFORMATION )                            QS028290
      ZED=ZET(I)                                                        QS028300
      IF(ETER.GT.CAPK)ZED=-ZED                                          QS028310
      IF(ETER.GT.CAPK) ETER=2.*CAPK-ETER                                QS028320
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```
      IF(I.EQ.ZNO)ZED=0.                                                QS028330
      ALLFNC=FUDS(ETER, ZED,M1)                                         QS028340
      LAM  = BADZAC(M1)                                                 QS028350
      TH   = OWOW(M1)                                                   QS028360
      X(I,J)= CHORD*A/PI*(LNK-2.*ALOG(ALLFNC/LAM))                      QS028370
      IF(J.GT.ENO.AND.I.EQ.ZN2M1)X(I,J)=-CHORD-X(I,J)                   QS028380
      IF(J.GT.ENO.AND.I.EQ.ZNO)X(I,J)=CHORD-X(I,J)                      QS028390
      Y(I,J)= 2.*A*CHORD/PI*TH                                          QS028400
      IF(X(I,J).GT.XDNS)X(I,J)=XDNS                                     QS028410
      IF(X(I,J).LT.XUPS)X(I,J)=XUPS                                     QS028420
C     END                                                               QS028430
                                                                        QS028440
271   CONTINUE                                                          QS028450
C     END                                                               QS028460
                                                                        QS028470
                                                                        QS028480
C     DO (SPECIAL POINTS)                                               QS028490
                                                                        QS028500
C     PROCEDURE (SPECIAL POINTS)                                        QS028510
      DO 278 J=1,ENOPLS                                                 QS028520
      X(1,J)=X(ZN2M1,J)                                                 QS028530
      Y(ZN2M1,J)=0.                                                     QS028540
      Y(ZNO,J)   =0.                                                    QS028550
278   Y(1,J)   =0.                                                      QS028560
C     END                                                               QS028570
                                                                        QS028580
                                                                        QS028590
      IF(STAG.EQ.0.)  GOTO 209                                          QS028600
                                                                        QS028610
                                                                        QS028620
C     DO (CIRCLE TRANSFM. FROM ZERO STAGGER TO INPUT VALUES)            QS028630
                                                                        QS028640
C     PROCEDURE (CIRCLE TRANSFM. FROM ZERO STAGGER TO INPUT VALUES)     QS028650
      CALL TOSTAG(S,ZET,CHORD)                                          QS028660
      CHORD=CHORB-RTE/2.-RLE/2.                                         QS028670
      LAMDAO=STAG                                                       QS028680
      SOLIDO=SOLFLT                                                     QS028690
      S=CHORD/SOLFLT                                                    QS028700
      OLDK=CAPK                                                         QS028710
      OLDKP=CAPKP                                                       QS028720
                                                                        QS028730
C     DO (CALCULATION OF GEOMETRY CONSTANTS)                            QS028740
C     PROCEDURE (CALCULATION OF GEOMETRY CONSTANTS)                     QS028750
      A= COS(LAMDAO)/2./SOLIDO                                          QS028760
      K= EXP(-PI/2./A)                                                  QS028770
      LNK = -ALOG(K)                                                    QS028780
      M=K*K                                                             QS028790
      DM=M                                                              QS028800
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      DM1=1.D0-DM                                                       QS028810
      M1=DM1                                                            QS028820
      CAPK=MMDELK(1,DM,IER)                                             QS028830
      CAPKP=MMDELK(1,DM1,IER)                                           QS028840
C     END                                                               QS028850
      DO 283 I1=1,ENOPLS                                                QS028860
  283 ET(I1)=ET(I1)*CAPK/OLDK                                           QS028870
      DO 287 I1=1,ZN2M1                                                 QS028880
  287 ZET(I1)=ZET(I1)*CAPKP/OLDKP                                       QS028890
C     END                                                               QS028900
                                                                        QS028910
                                                                        QS028920
  209 CONTINUE                                                          QS028930
                                                                        QS028940
                                                                        QS028950
C     DO (TRANSLATE ORIGIN OF INPUT BODY POINTS TO MIDCHORD)            QS028960
                                                                        QS028970
C     PROCEDURE (TRANSLATE ORIGIN OF INPUT BODY POINTS TO MIDCHORD)     QS028980
      DO 291 L=1,END                                                    QS028990
  291 XBOD(L)=XBOD(L)-RLE/2.-.5*CHORD                                   QS029000
C     END                                                               QS029010
                                                                        QS029020
                                                                        QS029030
C     DO (TRAILING EDGE FIX OF CAMBER POINTS)                           QS029040
                                                                        QS029050
C     PROCEDURE (TRAILING EDGE FIX OF CAMBER POINTS)                    QS029060
      ENOP1=ENO+1                                                       QS029070
      DO 295 J=ENOP1,ENOPLS                                             QS029080
      JNEXT=2*ENO-J                                                     QS029090
      FAD=1.                                                            QS029100
      IF(X(ZNO+1,ENO)-X(ZNO-1,ENO).NE.0.)                               QS029110
     1FAD=(X(ZNO,ENO)-X(ZNO-1,ENO))/(X(ZNO+1,ENO)-X(ZNO-1,ENO))         QS029120
      FAB=1.                                                            QS029130
      IF(X(2,ENO)-X(ZN2M1-1,ENO).NE.0.)                                 QS029140
     1FAB=(X(1,ENO)-X(ZN2M1-1,ENO))/(X(2,ENO)-X(ZN2M1-1,ENO))           QS029150
      X(ZNO,J)=X(ZNO-1,J)+FAD*(X(ZNO+1,J)-X(ZNO-1,J))                   QS029160
      Y(ZNO,J)=Y(ZNO-1,J)+FAD*(Y(ZNO+1,J)-Y(ZNO-1,J))                   QS029170
      X(1,J)=X(ZN2M1-1,J)+FAB*(X(2,J)-X(ZN2M1-1,J))                     QS029180
      Y(1,J)=Y(ZN2M1-1,J)+FAB*(Y(2,J)-Y(ZN2M1-1,J))                     QS029190
      X(ZN2M1,J)=X(1,J)                                                 QS029200
  295 Y(ZN2M1,J)=Y(1,J)                                                 QS029210
C     END                                                               QS029220
                                                                        QS029230
                                                                        QS029240
                                                                        QS029250
                                                                        QS029260
C     DO (ADDITION OF BLADE SURFACE ON CLEAN MESH)                      QS029270
      IF(DOSURF)  CALL SURFUP(ET,ZET,XBOD,YBOD,EF)                      QS029280
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7777  FORMAT(14E9.3)                                                    QS029290
                                                                        QS029300
                                                                        QS029310
                                                                        QS029320
      RETURN                                                            QS029330
                                                                        QS029340
                                                                        QS029350
                                                                        QS029360
                                                                        QS029370
                                                                        QS029380
                                                                        QS029390
                                                                        QS029400
                                                                        QS029410
                                                                        QS029420
                                                                        QS029430
                                                                        QS029440
                                                                        QS029450
                                                                        QS029460
                                                                        QS029470
                                                                        QS029480
                                                                        QS029490
      END                                                               QS029500
      DOUBLE PRECISION FUNCTION MMDELK(ILPT,ARG,IER)                    QS029510
C-----CALCS COMPLETE ELLIPTIC INTEGRAL OF FIRST KIND FOR MODULUS SQUAREDQS029520
C      = ARG                                                            QS029530
      DOUBLE PRECISION ARG,PI,A,B,C,A0,B0                               QS029540
      DATA PI/3.141592653589793D0/                                      QS029550
      IER = 130                                                         QS029560
      IF(ILPT.NE.1) STOP 105                                            QS029570
      IF(ARG.LT.0.D0.OR.ARG.GE.1.D0) GOTO40                             QS029580
      IER = 0                                                           QS029590
      A = 1.D0                                                          QS029600
      B = DSQRT(1.D0 - ARG)                                             QS029610
      DO 10 I = 1,15                                                    QS029620
      C = .5D0 * (A - B)                                                QS029630
      IF(DABS(C).LT.1.D-12) GOTO15                                      QS029640
      A0 = A                                                            QS029650
      B0 = B                                                            QS029660
      A = .5D0 * (A0 + B0)                                              QS029670
      B = DSQRT(A0 * B0)                                                QS029680
10    CONTINUE                                                          QS029690
15    IF(I.GT.15) STOP 110                                              QS029700
      MMDELK = .5D0 * PI / A                                            QS029710
40    RETURN                                                            QS029720
      END                                                               QS029730
      SUBROUTINE SURFUP(ET,ZET,XBOD,YBOD,EF)                            QS029740
                                                                        QS029750
                                                                        QS029760
```

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C         LOCATES INTERSECTION OF EACH RADIATING LINE IN THE FLATPLATE  QS029770
C     GRID WITH                                                         QS029780
C         THE DESIRED BODY SHAPE. ADJUSTS THE SURFACE CONTOURS ('ETA VA QS029790
C     LUE STRETCH')                                                     QS029800
C         SO THAT ALL RADIATING GRID LINES END ON THE BLADE.            QS029810
                                                                        QS029820
                                                                        QS029830
                                                                        QS029840
                                                                        QS029850
                                                                        QS029860
                                                                        QS029870
                                                                        QS029880
                                                                        QS029890
C     ET(ENO)=CAPK                                                      QS029900
C     DELSMX=.06667                                                     QS029910
C     PIO2=1.57079                                                      QS029920
C     THETT=THETT*PI/180.                                               QS029930
C     THETL=THETL*PI/180.                                               QS029940
C     ISA=1                                                             QS029950
C     PLATE=(CHORD-RLE/2.-RTE/2.)/2.                                    QS029960
C     DO (BODY COORDINATE LOADING)                                      QS029970
C     ZN2M1=2*ZNO-1                                                     QS029980
C     NZ2M2=ZN2M1-1                                                     QS029990
C     DO FOR I=1,NZ2M2                                                  QS030000
C        ENPOLS=ENOPLS                                                  QS030010
C        DO (ITERATION SETUP)                                           QS030020
C        DO (ITERATION FOR ETA LINE-BODY INTERSECTION)                  QS030030
C        DO FOR J=1,ENOPLS                                              QS030040
C           IF(ET(J).GE.ETA) THEN                                       QS030050
C           EXIT(J)                                                     QS030060
C           END                                                         QS030070
C        END                                                            QS030080
C        IF(J.EQ.ENOPLS+1) ETA=ET(ENOPLS)                               QS030090
C        IF(RELAXD) THEN                                                QS030100
C           XX(I,ENO)=X                                                 QS030110
C           YY(I,ENO)=Y                                                 QS030120
C           ETS(I)=ETA                                                  QS030130
C           DO (ETA VALUE STRETCH)                                      QS030140
C        END                                                            QS030150
C     END                                                               QS030160
C     DO (EDGE REGIONS)                                                 QS030170
C     DO FOR J1=2,ENO                                                   QS030180
C        XX(ZN2M1,J1)=XX(1,J1)                                          QS030190
C        YY(ZN2M1,J1)=YY(1,J1)                                          QS030200
C     END                                                               QS030210
C     RETURN                                                            QS030220
                                                                        QS030230
                                                                        QS030240
```

```
      DOUBLE PRECISION CAPK,CAPKP
      COMMON/GEOM/ZNO,ENO,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDA0,CC,CAPK
     1,CAPKP,PI
     *,LNK,M1,KM,END,M,DOSURF,AARR,SOL,ENOPLS
     1,SDUM(5),SMOOTH,CHOP,THETT,THETL,TDUM,LEONLY
      COMMON /ENTIRE/XX(100,30),YY(100,30)
      COMMON/SPGENC/DA,DSMAX,RMAX,THIN,DB,TMIN,DSEND
      COMMON/FUNCOS/S,C,D,SN,CN,DN
      COMMON/MAN/DELSMX,PIO2,DELS1,IHUB
      DIMENSION XBOD(200),YBOD(200),SU(400),SD(400),ET(100),ZET(100),
     1NSAVE(25),SEDGT(400),SEDGL(400),
     1ISAVE(25),ETS(100),SYYETA(400),SDXETA(400),SXYETA(400),SDYETA(400)
      INTEGER ZNO,ENO,END,ZN2M1,ENOPLS,ENDM1,ENPOLS,ENDMM1,ENM1
      LOGICAL DUM,RZTRP,IZTRP,THIN,DONE,SMOOTH,DOSURF,LEONLY
      LOGICAL TE,RELAXD,BOTTOM/.FALSE./,FAILD/.FALSE./,EDGES/.FALSE./
      COMPLEX FZTRP,DZTRP,FZ,  Z(400),Z2(400),XOETA(400),YOETA(400)
     1,EDGL(400),EDGT(400),XYETA(400),YYETA(400)
      REAL M,M1,LNK,LAMDA0
      NAMELIST/SPGENS/DA,DSMAX,RMAX,THIN,DB,TMIN,DSEND
      NAMELIST/TESY/I,IS,ETA,Y,X,SPX,SPY,SPE,ITST,DF1DN,DF2DN,DF3DX,
     1F1,F2,F3,DELN,DELX,DELY,FZ,SP
      NAMELIST/TESX/ XYETA,SXYETA,YYETA,SYYETA
      DATA Z/400*(1.E20,0.)/
      DATA Z2/400*(1.E20,0.)/
      DATA EDGT,EDGL,XOETA,YOETA,XYETA,YYETA/2400*(1.E20,0.)/


      ET(ENO)=CAPK
      DELSMX=.06667
      PIO2=1.57079
      THETT=THETT*PI/180.
      THETL=THETL*PI/180.
      ISA=1
      PLATE=(CHORD-RLE/2.-RTE/2.)/2.


C     DO (BODY COORDINATE LOADING)

C     PROCEDURE (BODY COORDINATE LOADING)

      IF(.NOT.SMOOTH) GOTO222
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      IF(LEONLY) GOTO1008                                               QS030730
                                                                        QS030740
      KMH=(KM+1)/2                                                      QS030750
      IF(MOD(KM,2).NE.0)KMH=KMH-1                                       QS030760
      DO 234 I1=1,KMH                                                   QS030770
      I5=I1+KMH                                                         QS030780
234   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS030790
      IF(MOD(KM,2).NE.0)                                                QS030800
     1Z(KMH+1)=CMPLX(XBOD(I5+1),YBOD(I5+1))                             QS030810
      IF(MOD(KM,2).NE.0)KMH=KMH+1                                       QS030820
      KWOW=KMH+1+END-KM-2-(KM+1)/2+KM/2                                 QS030830
      KMH1=KMH+1                                                        QS030840
      DO 240 I1=KMH1,KWOW                                               QS030850
      I5=END-I1+KMH                                                     QS030860
240   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS030870
      KWOWP1=KWOW+1                                                     QS030880
      ENDMM1=END-1                                                      QS030890
      DO 244 I1=KWOWP1,ENDMM1                                           QS030900
      I5=I1-END+(KM-1)/2+3-MOD(KM,2)                                    QS030910
244   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS030920
      GOTO225                                                           QS030930
1008  KMH=END-KM                                                        QS030940
      DO 226 I1=1,KMH                                                   QS030950
      I5=END-I1+1                                                       QS030960
226   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS030970
      KWOW=END-1                                                        QS030980
      KMH1=KMH+1                                                        QS030990
      DO 230 I1=KMH1,KWOW                                               QS031000
      I5=I1-KMH+1                                                       QS031010
230   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS031020
4447  FORMAT(6E13.5)                                                    QS031030
225   ENDM1=END-1                                                       QS031040
C     WRITE(6,1234) (Z(IW),IW=1,ENDM1),                                 QS031050
C    1(XBOD(IQ),YBOD(IQ),IQ=1,END)                                      QS031060
1234  FORMAT(10E13.6)                                                   QS031070
                                                                        QS031080
                                                                        QS031090
      DA=.17                                                            QS031100
C     WRITE(6,1235)                                                     QS031110
1235  FORMAT(55H0THE FOLLOWING IS A PRINT   OF THE Z MATRIX FROM SURFUP)QS031120
C     WRITE(6,*)Z                                                       QS031130
      CALL XYCALC(1,ENDM1,Z,SU,SD)                                      QS031140
C     WRITE(6,1236)                                                     QS031150
1236  FORMAT(69H0THE FOLLOWING IS A PRINT   OF Z,SU,SD MATRICES AFTER THQS031160
     +E CALL XYCALC)                                                    QS031170
C     WRITE(6,*)Z                                                       QS031180
C     WRITE(6,*)SU                                                      QS031190
C     WRITE(6,*)SD                                                      QS031200
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      END=ENDM1                                                         QS031210
      ITS=0.                                                            QS031220
      XTS=0.                                                            QS031230
      DO 248 I1=1,END                                                   QS031240
      IF(SU(I1).GT.XTS) ITS=I1                                          QS031250
      IF(SU(I1).GT.XTS) XTS=SU(I1)                                      QS031260
248   CONTINUE                                                          QS031270
      KMP=ITS                                                           QS031280
      ITS=0                                                             QS031290
      XTS=100.                                                          QS031300
      DO 254 I1=1,END                                                   QS031310
      IF(SU(I1).LT.XTS) ITS=I1                                          QS031320
      IF(SU(I1).LT.XTS) XTS=SU(I1)                                      QS031330
254   CONTINUE                                                          QS031340
      K1P=ITS                                                           QS031350
      KM=END-(K1P-KMP)                                                  QS031360
      KM1=KM+1                                                          QS031370
      END=END+1                                                         QS031380
      DO 260 I1=1,KM                                                    QS031390
      I5=K1P+I1-1                                                       QS031400
      IF(I5.GE.END-1)I5=I1-END+K1P+1                                    QS031410
      XBOD(I1)=SU(I5)                                                   QS031420
260   YBOD(I1)=SD(I5)                                                   QS031430
4448  FORMAT(4E13.5,3I7)                                                QS031440
                                                                        QS031450
C       LOAD SMOOTHED DATA AROUND L.E. REGION INTO EDGL FOR USE IN 'EDGE QS031460
C     REGION' TECHNIQUE                                                 QS031470
                                                                        QS031480
      DO 264 I1=KM1,END                                                 QS031490
      I5=END+KMP-I1                                                     QS031500
      XBOD(I1)=SU(I5)                                                   QS031510
264   YBOD(I1)=SD(I5)                                                   QS031520
      DO 268 I1=KMP,K1P                                                 QS031530
      IF(SU(I1).LT.-CHOP*.50*PLATE) GOTO271                             QS031540
268   CONTINUE                                                          QS031550
      I1=K1P                                                            QS031560
271   I2L=0                                                             QS031570
      DO 274 I3=I1,END                                                  QS031580
      IF(ABS(SU(I3)).LT.CHOP*.50*PLATE) GOTO277                         QS031590
      YEE=SU(I3)*SIN(THETL)+SD(I3)*COS(THETL)                           QS031600
      I2L=I2L+1                                                         QS031610
274   EDGL(I2L)=CMPLX(YEE,SU(I3))                                       QS031620
277   NOTO=SGEN(SEDGL,EDGL,I2L)                                         QS031630
                                                                        QS031640
C       IF (.NOT.LEONLY) LOAD SMOOTHED DATA AROUND T.E. INTO EDGT FOR USEQS031650
C       IN 'EDGE REGION'                                                QS031660
                                                                        QS031670
      IF(LEONLY) GOTO280                                                QS031680
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      DO 282 I1=1,KMP                                                   QS031690
      IF(SU(I1).GT.CHOP*.50*PLATE) GOTO285                              QS031700
282   CONTINUE                                                          QS031710
285   I2T=0                                                             QS031720
      DO 288 I3=I1,K1P                                                  QS031730
      IF(SU(I3).LT.CHOP*.50*PLATE) GOTO291                              QS031740
      YEE=SU(I3)*SIN(THETT)+SD(I3)*COS(THETT)                           QS031750
      I2T=I2T+1                                                         QS031760
288   EDGT(I2T)=CMPLX(YEE,SU(I3))                                       QS031770
291   NOTO=SGEN(SEDGT,EDGT,I2T)                                         QS031780
                                                                        QS031790
                                                                        QS031800
                                                                        QS031810
280   DO 298 I1=1,400                                                   QS031820
      Z(I1)=1.E20                                                       QS031830
      IF(I1.LE.400) SU(I1)=0.                                           QS031840
      IF(I1.LE.400)SD(I1)=0.                                            QS031850
298   CONTINUE                                                          QS031860
222   DO 2100 I1=1,KM                                                   QS031870
2100  Z(I1)=CMPLX(XBOD(I1),YBOD(I1))                                    QS031880
      NOTO= SGEN(SU,Z,KM)                                               QS031890
      KM1=KM+1                                                          QS031900
      IF(NOTO.NE.0) WRITE(6,2) NOTO                                     QS031910
2     FORMAT('OSGEN FAILURE',I6)                                        QS031920
      KENDO=END-KM                                                      QS031930
      DO 2104 I1=KM1,END                                                QS031940
      I2=I1-KM                                                          QS031950
2104  Z2(I2)=CMPLX(XBOD(I1),YBOD(I1))                                   QS031960
      NOTO=SGEN(SD,Z2,KENDO)                                            QS031970
C     END OF BODY COORDINATE LOADING                                    QS031980
                                                                        QS031990
      ZN2M1=2*ZNO-1                                                     QS032000
      NZ2M2=ZN2M1-1                                                     QS032010
                                                                        QS032020
                                                                        QS032030
                                                                        QS032040
      DO 202 I=1,NZ2M2                                                  QS032050
      ENPOLS=ENOPLS                                                     QS032060
                                                                        QS032070
                                                                        QS032080
C     DO (ITERATION SETUP)                                              QS032090
                                                                        QS032100
C     PROCEDURE (ITERATION SETUP)                                       QS032110
      ENPOLS=ENOPLS                                                     QS032120
      RELAXD=.FALSE.                                                    QS032130
      FAILD=.FALSE.                                                     QS032140
      EDGES=.FALSE.                                                     QS032150
      BOTTOM=.FALSE.                                                    QS032160
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                                                                        QS032170
                                                                        QS032180
C     DO (GRID-LINE COORDINATE LOADING)                                 QS032190
                                                                        QS032200
C     PROCEDURE (GRID-LINE COORDINATE LOADING)                          QS032210
      ITST=0                                                            QS032220
      JTST=0                                                            QS032230
      DO 20109 I1=1,400                                                 QS032240
      XOETA(I1)=1.E20                                                   QS032250
      YOETA(I1)=1.E20                                                   QS032260
      IF(I1.LE.400) SDXETA(I1)=0.                                       QS032270
      IF(I1.LE.400)SDYETA(I1)=0.                                        QS032280
20109 CONTINUE                                                          QS032290
      DO 20115 I1=1,ENPOLS                                              QS032300
      IF(ABS(XX(I,1)).GT.20.)XX(I,1)=SIGN(7.*ABS(XX(I,2)),XX(I,1))      QS032310
      XOETA(I1)=CMPLX(ET(I1),XX(I,I1))                                  QS032320
20115 YOETA(I1)=CMPLX(ET(I1),YY(I,I1))                                  QS032330
      NOTO=SGEN(SDYETA,YOETA,ENPOLS)                                    QS032340
      IF(NOTO.NE.0) WRITE(6,2) NOTO                                     QS032350
      NOTO=SGEN(SDXETA,XOETA,ENPOLS)                                    QS032360
      IF(NOTO.NE.0) WRITE(6,2) NOTO                                     QS032370
C     END                                                               QS032380
                                                                        QS032390
      Y=YY(I,ENO)                                                       QS032400
      IF(Y.EQ.0.)Y=SIGN(1.E-04,YY(I,ENO-1))                             QS032410
      X=XX(I,ENO-1)                                                     QS032420
      XOO=X                                                             QS032430
      ETA= CAPK*(ENO-2)/(ENO-1)                                         QS032440
      IF(Y.LE.0..AND.I.NE.1)BOTTOM=.TRUE.                               QS032450
      IF(I.EQ.ZNO.AND.LAMDAO.GT.0.)BOTTOM=.TRUE.                        QS032460
      DF1DN=(XX(I,ENO)-XX(I,ENO-1))/(ET(ENO-1)-ET(ENO))                 QS032470
      DF2DN=(YY(I,ENO)-YY(I,ENO-1))/(ET(ENO-1)-ET(ENO))                 QS032480
      DF3DX=0.                                                          QS032490
      IF(DF2DN+DF1DN*DF3DX.EQ.0.)DF3DX=1.                               QS032500
      DELN=0.                                                           QS032510
      DELX=0.                                                           QS032520
      DELY=0.                                                           QS032530
      SP=0.                                                             QS032540
C     END                                                               QS032550
                                                                        QS032560
C     DO (ITERATION FOR ETA LINE-BODY INTERSECTION)                     QS032570
                                                                        QS032580
C     PROCEDURE (ITERATION FOR ETA LINE-BODY INTERSECTION)              QS032590
      IF(ABS(XX(I,ENO)).GT.CHOP*PLATE.AND.                              QS032600
     1((.NOT.LEONLY.OR.I.LE.ZNO/2.OR.I.GE.3*ZNO/2))) GOTO2119           QS032610
C     DO UNTIL(RELAXD.OR.FAILD)                                         QS032620
2122  ITST=ITST+1                                                       QS032630
      X=X+DELX                                                          QS032640
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      Y=Y+DELY
      SPY=0.
      SPX=0.
      SP=0.
      SPE=0.
      ETA=ETA+DELN
      IF(ETA.LT.0.)ETA=ET(2)
      IF(ETA.GT.2.*CAPK)ETA=ET(ENOPLS)
      IF(.NOT.EDGES) GOTO2124
      IF(ETA.GT..90*CAPK.AND.ITST.GT.20)ETA=.90*CAPK
      DUM=RZTRP(SXYETA,XYETA,ETA,I2S,SPX)
      GETA=AIMAG(FZTRP(SXYETA,XYETA,SPX,I2S))
      DUM=RZTRP(SYYETA,YYETA,ETA,I2Y,SPY)
      FETA=AIMAG(FZTRP(SYYETA,YYETA,SPY,I2Y))
      GOTO2125
 2124 DUM=RZTRP(SDXETA,XOETA,ETA,ENPOLS,SPX)
      GETA=AIMAG(FZTRP(SDXETA,XOETA,SPX,ENPOLS))
      DUM=RZTRP(SDYETA,YOETA,ETA,ENPOLS,SPY)
      FETA=AIMAG(FZTRP(SDYETA,YOETA,SPY,ENPOLS))
 2125 F1=X-GETA
      F2=Y-FETA
      IF(.NOT.BOTTOM) GOTO2126
      DUM=RZTRP(SD,Z2,X,KENDO,SP)
      FX=AIMAG(FZTRP(SD,Z2,SP,KENDO))
      GOTO2127
 2126 DUM=RZTRP(SU,Z,X,KM,SP)
      FX=AIMAG(FZTRP(SU,Z,SP,KM))
 2127 F3 = Y-FX
      RELAXD=(ABS(F1)+ABS(F2)+ABS(F3)).LT..0001

C      IF FIRST TRY IS UNSUCCESSFUL, GET SMOOTHED SLOPE DATA AND TRY AGA
C     IN

      IF((ITST.LE.20.AND.ABS(DELN/ETA).LE.1000.).OR.EDGES) GOTO2128
C     DO (ITERATION WITH BETTER SLOPES)

C     PROCEDURE(ITERATION WITH BETTER SLOPES)
      WRITE(6,5) I
 5    FORMAT('OITERATION PROCEEDS WITH SMOOTHER SLOPE DATA FOR LINE ',I4
     1)
      DO 2139 I1=1,400
      XYETA(I1)=1.E20
      YYETA(I1)=1.E20
      IF(I1.LE.400) SXYETA(I1)=0.
      IF(I1.LE.400)SYYETA(I1)=0.
 2139 CONTINUE

C     DO (ITERATION SETUP AGAIN)
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C     PROCEDURE (ITERATION SETUP)                                       QS033130
      ENPOLS=ENOPLS                                                     QS033140
      RELAXD=.FALSE.                                                    QS033150
      FAILD=.FALSE.                                                     QS033160
      EDGES=.FALSE.                                                     QS033170
      BOTTOM=.FALSE.                                                    QS033180
                                                                        QS033190
C     DO (GRID-LINE COORDINATE LOADING AGAIN)                           QS033200
C     PROCEDURE (GRID-LINE COORDINATE LOADING)                          QS033210
      ITST=0                                                            QS033220
      JTST=0                                                            QS033230
      DO 2109 I1=1,400                                                  QS033240
      XOETA(I1)=1.E20                                                   QS033250
      YOETA(I1)=1.E20                                                   QS033260
      IF(I1.LE.400) SDXETA(I1)=0.                                       QS033270
      IF(I1 .LE.400)SDYETA(I1)=0.                                       QS033280
 2109 CONTINUE                                                          QS033290
      DO 21115 I1=1,ENPOLS                                              QS033300
      IF(ABS(XX(I,1)).GT.20.)XX(I,1)=SIGN(7.*ABS(XX(I,2)),XX(I,1))      QS033310
      XOETA(I1)=CMPLX(ET(I1),XX(I,I1))                                  QS033320
21115 YOETA(I1)=CMPLX(ET(I1),YY(I,I1))                                  QS033330
      NOTO=SGEN(SDYETA,YOETA,ENPOLS)                                    QS033340
      IF(NOTO.NE.0) WRITE(6,2) NOTO                                     QS033350
      NOTO=SGEN(SDXETA,XOETA,ENPOLS)                                    QS033360
      IF(NOTO.NE.0) WRITE(6,2) NOTO                                     QS033370
C     END                                                               QS033380
                                                                        QS033390
      Y=YY(I,ENO)                                                       QS033400
      IF(Y.EQ.0.)Y=SIGN(1.E-04,YY(I,ENO-1))                             QS033410
      X=XX(I,ENO-1)                                                     QS033420
      XOO=X                                                             QS033430
      ETA= CAPK*(ENO-2)/(ENO-1)                                         QS033440
      IF(Y.LE.0..AND.I.NE.1)BOTTOM=.TRUE.                               QS033450
      IF(I.EQ.ZNO.AND.LAMDAO.GT.0.)BOTTOM=.TRUE.                        QS033460
      DF1DN=(XX(I,ENO)-XX(I,ENO-1))/(ET(ENO-1)-ET(ENJ))                 QS033470
      DF2DN=(YY(I,ENO)-YY(I,ENO-1))/(ET(ENO-1)-ET(ENO))                 QS033480
      DF3DX=0.                                                          QS033490
      IF(DF2DN+DF1DN*DF3DX.EQ.0.)DF3DX=1.                               QS033500
      DELN=0.                                                           QS033510
      DELX=0.                                                           QS033520
      DELY=0.                                                           QS033530
      SP=0.                                                             QS033540
C     END                                                               QS033550
                                                                        QS033560
      EDGES=.TRUE.                                                      QS033570
      DO 2146 I6=1,ENO                                                  QS033580
C     DO 2146 I6=1,ENOPLS                                               QS033590
      XYETA(I6)=XOETA(I6)                                               QS033600
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2146  YYETA(I6)=YOETA(I6)                                                QS033610
      DA=.02                                                             QS033620
      DELSMX=.06667                                                      QS033630
C     I2S=ENOPLS                                                         QS033640
C      SMOOTH THE SLOPE DATA                                             QS033650
      CALL XYCALC(1,I2S,XYETA,SXYETA,SYYETA)                             QS033660
      DO 2150 I6=1,I2S                                                   QS033670
2150  XYETA(I6)=CMPLX(SXYETA(I6),SYYETA(I6))                             QS033680
      DO 2154 I4=1,400                                                   QS033690
      SXYETA(I4)=0.                                                      QS033700
2154  SYYETA(I4)=0.                                                      QS033710
C     I2Y=ENOPLS                                                         QS033720
      CALL XYCALC(1,I2Y,YYETA,SXYETA,SYYETA)                             QS033730
      DELSMX=.066667                                                     QS033740
      DO 2158 I6=1,I2Y                                                   QS033750
2158  YYETA(I6)=CMPLX(SXYETA(I6),SYYETA(I6))                             QS033760
      NOTO=SGEN(SXYETA,XYETA,I2S)                                        QS033770
      NOTO=SGEN(SYYETA,YYETA,I2Y)                                        QS033780
C     WRITE(6,TESX)                                                      QS033790
C      END OF BETTER SLOPE ACQUISITION, EDGES NOW = .TRUE.               QS033800
2128  IF(ITST.GT.50.OR.ABS(DELN/ETA).GT.1000.) FAILD=.TRUE.              QS033810
      IF(RELAXD) GOTO2129                                                QS033820
      DELN = (F3-F2-DF3DX*F1)/(DF2DN+DF1DN*DF3DX)                        QS033830
      DELX=-F1-DF1DN*DELN                                                QS033840
      DELY = -F3 -DF3DX*DELX                                             QS033850
C     DO (SEARCH FOR BODY SLOPE)                                         QS033860
C     PROCEDURE (SEARCH FOR BODY SLOPE)                                  QS033870
      K4=1                                                               QS033880
      K3=KM                                                              QS033890
      K2=1                                                               QS033900
      IF(.NOT.BOTTOM) GOTO2162                                           QS033910
      K2=KM+1                                                            QS033920
      K3=END                                                             QS033930
      K4=1                                                               QS033940
2162  DO 2164 K1=K2,K3,K4                                                QS033950
      IF(XBOD(K1).GE. X+DELX) GOTO2167                                   QS033960
2164  CONTINUE                                                           QS033970
      K1=K3                                                              QS033980
2167  DF3DX=(YBOD(K1-1)-YBOD(K1))/                                       QS033990
     * (XBOD(K1)-XBOD(K1-1))                                             QS034000
C     END                                                                QS034010
                                                                         QS034020
C     DO (SEARCH FOR GRID-LINE SLOPE)                                    QS034030
C     PROCEDURE (SEARCH FOR GRID-LINE SLOPE)                             QS034040
      IF(.NOT.EDGES) GOTO2170                                            QS034050
      DO 2172 J=1,I2S                                                    QS034060
      IF(REAL(XYETA(J)).GE.ETA) GOTO2175                                 QS034070
2172  CONTINUE                                                           QS034080
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2175  IF(J.EQ.I2S+1) J=I2S                                              QS034090
      DO 2180 JY=1,I2Y                                                  QS034100
      IF(REAL(YYETA(JY)).GE.ETA) GOTO2183                               QS034110
2180  CONTINUE                                                          QS034120
2183  IF(JY.EQ.I2Y+1) JY=I2Y                                            QS034130
      DF1DN=(AIMAG(XYETA(J))-AIMAG(XYETA(J-1)))/                        QS034140
     1(REAL(XYETA(J-1))-REAL(XYETA(J)))                                 QS034150
      DF2DN=(AIMAG(YYETA(JY))-AIMAG(YYETA(JY-1)))/                      QS034160
     1(REAL(YYETA(JY-1))-REAL(YYETA(JY)))                               QS034170
      GOTO2171                                                          QS034180
2170  DO 2188 J=1,ENOPLS                                                QS034190
      IF(ET(J).GE.ETA) GOTO2191                                         QS034200
2188  CONTINUE                                                          QS034210
2191  IF(J.EQ.ENOPLS+1) J=ENOPLS                                        QS034220
      DF1DN=(XX(I,J)-XX(I,J-1))/(ET(J-1)-ET(J))                         QS034230
      DF2DN=(YY(I,J)-YY(I,J-1))/(ET(J-1)-ET(J))                         QS034240
2171  CONTINUE                                                          QS034250
C     END                                                               QS034260
                                                                        QS034270
2129  IF(.NOT.(DF2DN+DF3DX.EQ.0..OR.                                    QS034280
     1((I.EQ.1.OR.I.EQ.ZNO).AND.LAMDAO.EQ.0.).OR.                       QS034290
     1(.NOT.SMOOTH.AND.ABS(XX(I,ENO)).GT..98*PLATE.AVD.FAILD))) GOTO2121QS034300
      RELAXD=.TRUE.                                                     QS034310
      FAILD=.FALSE.                                                     QS034320
      Y=YY(I,ENO)                                                       QS034330
      X=XBOD(KM)                                                        QS034340
      IF(I.EQ.1)X=XBOD(1)                                               QS034350
      IF(SMOOTH) GOTO2135                                               QS034360
      Y=0.                                                              QS034370
      X=XBOD(1)                                                         QS034380
      IF(I.GT.ZNO/2.AND.I.LT.3*ZNO/2)X=XBOD(KM)                         QS034390
2135  DUM=IZTRP(SDXETA,XOETA,X,ENO,SPE)                                 QS034400
      ETA=REAL(FZTRP(SDXETA,XOETA,SPE,ENO))                             QS034410
                                                                        QS034420
2121  IF(.NOT.(RELAXD.OR.FAILD))GOTO2122                                QS034430
C     END OF ITERATION FOR ETA LINE-BODY  INTERSECTION                  QS034440
2119  IF(RELAXD.OR.ABS(XX(I,ENO)).LE.CHOP*PLATE.AND..NOT.FAILD) GOTO3004QS034450
      IF(FAILD)WRITE(6,3) I                                             QS034460
      IF(.NOT.FAILD)WRITE(6,4) I,XX(I,ENO),PLATE                        QS034470
3     FORMAT('0ITERATION FAILD FOR LINE ',I4,                           QS034480
     1' PROCEEDING TO EDGE REGION TECHNIQUE')                           QS034490
4     FORMAT('0ITERATION NOT ATTEMPTED FOR LINE ',I4,                   QS034500
     1', BODY X TOO CLOSE TO LE OR TE: ',2E15.6,'PROCEED TO EDGE TECH.')QS034510
      ISAVE(ISA)=I                                                      QS034520
      NSAVE(ISA)=1                                                      QS034530
      IF(BOTTOM)NSAVE(ISA)=-1                                           QS034540
      ISA=ISA+1                                                         QS034550
3004  DO 208 J=1,ENOPLS                                                 QS034560
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      IF(ET(J).GE.ETA) GOTO211                                          QS034570
208   CONTINUE                                                          QS034580
211   IF(J.EQ.ENOPLS+1) ETA=ET(ENOPLS)                                  QS034590
      IF(.NOT.RELAXD) GOTO202                                           QS034600
      XX(I,ENO)=X                                                       QS034610
      YY(I,ENO)=Y                                                       QS034620
      ETS(I)=ETA                                                        QS034630
C     DO (ETA VALUE STRETCH)                                            QS034640
C     PROCEDURE (ETA VALUE STRETCH)                                     QS034650
      ENM1=ENO-1                                                        QS034660
      DO 20196 J=2,ENM1                                                 QS034670
      ETANEW=ET(J)/CAPK*ETA                                             QS034680
      SPX=SDXETA(1)                                                     QS034690
      SPY=SDYETA(1)                                                     QS034700
      DUM=RZTRP(SDXETA,XOETA,ETANEW,ENPOLS,SPX)                         QS034710
      XX(I,J)=AIMAG(FZTRP(SDXETA,XOETA,SPX,ENPOLS))                     QS034720
      DUM=RZTRP(SDYETA,YOETA,ETANEW,ENPOLS,SPY)                         QS034730
20196 YY(I,J)=AIMAG(FZTRP(SDYETA,YOETA,SPY,ENPOLS))                     QS034740
C     END                                                               QS034750
                                                                        QS034760
                                                                        QS034770
202   CONTINUE                                                          QS034780
C     DO (EDGE REGIONS)                                                 QS034790
C     PROCEDURE (EDGE REGIONS)                                          QS034800
C                                                                       QS034810
C 'EDGE REGION TECHNIQUE' = INTERPOLATE ON CURVE OF INTERSECTION POINTS QS034820
C                           DEFINED BY SUCCESSFUL NEIGHBORING LINES.    QS034830
C                                                                       QS034840
      NOZO2=ZNO/2                                                       QS034850
      IF(ISAVE(1).GE.NOZO2) GOTO2020                                    QS034860
      DO 2202 I3=1,ISA                                                  QS034870
      IF(ISAVE(I3).GT.NOZO2) GOTO2205                                   QS034880
2202  CONTINUE                                                          QS034890
      I3=ISA                                                            QS034900
2205  I3=I3-1                                                           QS034910
      ISAP=ISA                                                          QS034920
      DO 2208 I4=1,I3                                                   QS034930
      ISAVE(ISAP)=ISAVE(I4)                                             QS034940
2208  ISAP=ISAP+1                                                       QS034950
      ISAM1=ISA-1                                                       QS034960
      DO 2212 I4=1,ISAM1                                                QS034970
      I4I3=I4+I3                                                        QS034980
2212  ISAVE(I4)=ISAVE(I4I3)                                             QS034990
2020  DO 2216 I1=1,400                                                  QS035000
      XYETA(I1)=1.E20                                                   QS035010
      YYETA(I1)=1.E20                                                   QS035020
      IF(I1.GT.400) GOTO2216                                            QS035030
      SXYETA(I1)=0.                                                     QS035040
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      SYYETA(I1)=0.                                                     QS035050
      SU(I1)=0.                                                         QS035060
      SD(I1)=0.                                                         QS035070
2216  CONTINUE                                                          QS035080
      I2=0                                                              QS035090
      IS=1                                                              QS035100
      NZ2M11=ZN2M1-1                                                    QS035110
                                                                        QS035120
C      LOAD VALUES OF BODY Y AND ZET FROM  ALL SUCCESSFUL LINE ITERATIONQS035130
C     S INTO                                                            QS035140
C      THE ARRAY XYETA AND SMOOTH IT.                                   QS035150
      DO 2222 I1=NOZ02,NZ2M11                                           QS035160
      IF(IS.GT.ISA) GOTO2222                                            QS035170
      IF(ISAVE(IS).EQ.I1) GOTO2228                                      QS035180
      I2=I2+1                                                           QS035190
      THE=XX(I1,ENO)*(THETL-THETT)/(-1.6*CHOP*PLATE)                    QS035200
      IF(XX(I1,ENO).LT.-CHOP*.80*PLATE)THE=THETL                        QS035210
      IF(XX(I1,ENO).GT.CHOP*.80*PLATE)THE=THETT                         QS035220
      YEE=YY(I1,ENO)*COS(THE)+XX(I1,ENO)*SIN(THE)                       QS035230
      YEE=YEE*10.                                                       QS035240
      XYETA(I2)=CMPLX(ZET(I1),YEE)                                      QS035250
      YYETA(I2)=CMPLX(ZET(I1),ETS(I1))                                  QS035260
2228  IF(ISAVE(IS).EQ.I1)IS=IS+1                                        QS035270
2222  CONTINUE                                                          QS035280
      DO 2230 I1=1,NOZ02                                                QS035290
      IF(ISAVE(IS).EQ.I1) GOTO2234                                      QS035300
      I2=I2+1                                                           QS035310
      ZED=ZET(I1)-2.*CAPKP                                              QS035320
      THE=XX(I1,ENO)*(THETL-THETT)/(-1.6*PLATE)                         QS035330
      IF(XX(I1,ENO).LT.-CHOP*.80*PLATE)THE=THETL                        QS035340
      IF(XX(I1,ENO).GT.CHOP*.80*PLATE)THE=THETT                         QS035350
      YEE=YY(I1,ENO)*COS(THE)+XX(I1,ENO)*SIN(THE)                       QS035360
      YEE=YEE*10.                                                       QS035370
      XYETA(I2)=CMPLX(ZED,YEE)                                          QS035380
      YYETA(I2)=CMPLX(ZED,ETS(I1))                                      QS035390
2234  IF(ISAVE(IS).EQ.I1)IS=IS+1                                        QS035400
2230  CONTINUE                                                          QS035410
      I2S=I2                                                            QS035420
      DELSMX=.5                                                         QS035430
      DA=.05                                                            QS035440
      CALL XYCALC(1,I2S,XYETA,SU,SD)                                    QS035450
      DELSMX=.066667                                                    QS035460
      DO 2236 I6=1,I2S                                                  QS035470
2236  XYETA(I6)=CMPLX(SU(I6),SD(I6))                                    QS035480
      NOTO=SGEN(SXYETA,XYETA,I2S)                                       QS035490
      NOTO=SGEN(SYYETA,YYETA,I2)                                        QS035500
C     WRITE(6,TESX)                                                     QS035510
      SPT=0.                                                            QS035520
```

```
      SPL=0.                                                            QS035530
      ISAM1=ISA-1                                                       QS035540
      DO 2240 IS=1,ISAM1                                                QS035550
      SPX=0.                                                            QS035560
      SPE=0.                                                            QS035570
      TE=.FALSE.                                                        QS035580
      I1=ISAVE(IS)                                                      QS035590
      I=I1                                                              QS035600
      IMM1=I-1                                                          QS035610
      IF(IMM1.EQ.0)IMM1=ZN2M1-1                                         QS035620
                                                                        QS035630
                                                                        QS035640
      IF(I.GT.ZN2M1/4.AND.I.LT.3*ZN2M1/4)TE=.TRUE.                      QS035650
                                                                        QS035660
                                                                        QS035670
      IF(TE)SPL=0.                                                      QS035680
      ZED=ZET(I1)                                                       QS035690
                                                                        QS035700
C      INTERPOLATE ON THE TABLE OF Y VALUES IN XYETA USING THE KNOWN VALQS035710
C     UE OF ZETA                                                        QS035720
C      FOR EACH UNSUCCESSFUL LINE.                                      QS035730
                                                                        QS035740
      IF(.NOT.TE.AND.ZED.GT..85*CAPKP)ZED=ZED-2.*CAPKP                  QS035750
      DUM=RZTRP(SXYETA,XYETA,ZED,I2S,SPX)                               QS035760
      Y=AIMAG(FZTRP(SXYETA,XYETA,SPX,I2S))/10.                          QS035770
                                                                        QS035780
                                                                        QS035790
C      AFTER Y IS FOUND, OBTAIN X FROM TABLE OF L.E. AND T.E. BODY SHAPEQS035800
C     S                                                                 QS035810
C      IN EDGL AND EDGT.                                                QS035820
                                                                        QS035830
                                                                        QS035840
      IF(.NOT.SMOOTH) GOTO2244                                          QS035850
      IF( .NOT.TE) GOTO2246                                             QS035860
      DUM=RZTRP(SEDGT,EDGT,Y,I2T,SPT)                                   QS035870
      X=AIMAG(FZTRP(SEDGT,EDGT,SPT,I2T))                                QS035880
      IF(ABS(X-XX(IMM1,ENO)).LE.1.5/FLOAT(ZNO)) GOTO22461               QS035890
      DUM=RZTRP(SEDGT,EDGT,Y,I2T,SPT)                                   QS035900
      X=AIMAG(FZTRP(SEDGT,EDGT,SPT,I2T))                                QS035910
22461 GOTO2245                                                          QS035920
2246  DUM=RZTRP(SEDGL,EDGL,Y,I2L,SPL)                                   QS035930
      X=AIMAG(FZTRP(SEDGL,EDGL,SPL,I2L))                                QS035940
      IF(ABS(X-XX(IMM1,ENO)).LE.1.5/FLOAT(ZNO)) GOTO22441               QS035950
      DUM=RZTRP(SEDGL,EDGL,Y,I2L,SPL)                                   QS035960
      X=AIMAG(FZTRP(SEDGL,EDGL,SPL,I2L))                                QS035970
22441 GOTO2245                                                          QS035980
2244  IF(Y.GT.0..OR.I.EQ.1) GOTO2252                                    QS035990
      DUM=IZTRP(SD,Z2,Y,KENDO,SP)                                       QS036000
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      X=REAL(FZTRP(SD,Z2,SP,KENDO))                                     QS036010
      GOTO2245                                                          QS036020
2252  DUM=IZTRP(SU,Z,Y,KM,SP)                                           QS036030
      X=REAL(FZTRP(SU,Z,SP,KM))                                         QS036040
                                                                        QS036050
                                                                        QS036060
2245  IF(.NOT.TE)Y=(Y-X*SIN(THETL))/COS(THETL)                          QS036070
      IF(TE)Y=(Y-X*SIN(THETT))/COS(THETT)                               QS036080
C     DO (GRID-LINE COORDINATE LOADING)                                 QS036090
C     PROCEDURE (GRID-LINE COORDINATE LOADING)                          QS036100
      ITST=0                                                            QS036110
      JTST=0                                                            QS036120
      DO 21109 I1=1,400                                                 QS036130
      XOETA(I1)=1.E20                                                   QS036140
      YOETA(I1)=1.E20                                                   QS036150
      IF(I1.LE.400) SDXETA(I1)=0.                                       QS036160
      IF(I1.LE.400)SDYETA(I1)=0.                                        QS036170
21109 CONTINUE                                                          QS036180
      DO 2115 I1=1,ENPOLS                                               QS036190
      IF(ABS(XX(I,1)).GT.20.)XX(I,1)=SIGN(7.*ABS(XX(I,2)),XX(I,1))      QS036200
      XOETA(I1)=CMPLX(ET(I1),XX(I,I1))                                  QS036210
2115  YOETA(I1)=CMPLX(ET(I1),YY(I,I1))                                  QS036220
      NOTO=SGEN(SDYETA,YOETA,ENPOLS)                                    QS036230
      IF(NOTO.NE.0) WRITE(6,2) NOTO                                     QS036240
      NOTO=SGEN(SDXETA,XOETA,ENPOLS)                                    QS036250
      IF(NOTO.NE.0) WRITE(6,2) NOTO                                     QS036260
C     END                                                               QS036270
      DUM=IZTRP(SDXETA,XOETA,X,ENPOLS,SPE)                              QS036280
      ETA=REAL(FZTRP(SDXETA,XOETA,SPE,ENPOLS))                          QS036290
                                                                        QS036300
                                                                        QS036310
C     DO (ETA VALUE STRETCH FOR EDGE REGION POINTS)                     QS036320
                                                                        QS036330
C     PROCEDURE (ETA VALUE STRETCH)                                     QS036340
      ENM1=ENO-1                                                        QS036350
      DO 2196 J=2,ENM1                                                  QS036360
      ETANEW=ET(J)/CAPK*ETA                                             QS036370
      SPX=0.                                                            QS036380
      SPY=0.                                                            QS036390
      DUM=RZTRP(SDXETA,XOETA,ETANEW,ENPOLS,SPX)                         QS036400
      XX(I,J)=AIMAG(FZTRP(SDXETA,XOETA,SPX,ENPOLS))                     QS036410
      DUM=RZTRP(SDYETA,YOETA,ETANEW,ENPOLS,SPY)                         QS036420
2196  YY(I,J)=AIMAG(FZTRP(SDYETA,YOETA,SPY,ENPOLS))                     QS036430
C     END                                                               QS036440
      IF(XX(I,1).EQ.XX(I,ENO-1).AND.YY(I,1).EQ.YY(I,ENO-1)) WRITE (6,7)IQS036450
7     FORMAT('OGRID LINE NO. ',I4,' HAS DEGENERATED TO POINT.',         QS036460
     1' TRY THETL,THETT = LE,TE CAMBER ANGLES')                         QS036470
      XX(I,ENO)=X                                                       QS036480
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2240  YY(I,ENO)=Y                                                            QS036490
C     END                                                                    QS036500
      DO 218 J1=2,ENO                                                        QS036510
      XX(ZN2M1,J1)=XX(1,J1)                                                  QS036520
218   YY(ZN2M1,J1)=YY(1,J1)                                                  QS036530
      RETURN                                                                 QS036540
                                                                             QS036550
                                                                             QS036560
                                                                             QS036570
                                                                             QS036580
                                                                             QS036590
                                                                             QS036600
                                                                             QS036610
                                                                             QS036620
                                                                             QS036630
                                                                             QS036640
                                                                             QS036650
      END                                                                    QS036660
      SUBROUTINE TOSTAG(S,ZET,CHORDO)                                        QS036670
                                                                             QS036680
C      INVERT THE CONFORMAL TRANSFORMATION FROM FLATPLATE CASCADE OF ZERQS036690
C     O STAGGER                                                              QS036700
C      TO THE UNIT CIRCLE. ADD DESIRED SOLIDITY AND STAGGER TERMS AND REQS036710
C     VERT TO                                                                QS036720
C      PHYSICAL PLANE.                                                       QS036730
                                                                             QS036740
C       SOURCE,     HAWTHORNE (LISTED AS REF. 4 OF REF. 2 OF THE USERS MQS036750
C     ANUAL)                                                                 QS036760
                                                                             QS036770
                                                                             QS036780
      INTEGER ZNO,ZN2M1,ENO,ENOPLS                                           QS036790
      DIMENSION ZET(100)                                                     QS036800
      COMMON/GEOM/ZNO,ENO,RLE,RTE,A,CHORD,XUPS,XDNS,STAG,F,CAKK(4),PI,       QS036810
     1LNK,VB,KN,NED,BB,DOSURF,R,SOLID2,ENOPLS                                QS036820
      COMMON /ENTIRE/ XGRID(100,30),YGRID(100,30)                            QS036830
      COMPLEX AI/(0.,1.)/,AHTAN,AHTAN2,AHYPT,ZCMX,WCMX,AQT1,AQT2,READK        QS036840
      COMPLEX ZGRID                                                          QS036850
      READK=1./R                                                             QS036860
      ALAMDA=.5*(READK+1./READK)                                             QS036870
      ZN2M1=2*ZNO-1                                                          QS036880
      N2ZM11=ZN2M1-1                                                         QS036890
      XGRID(1,1)=4.*XGRID(2,1)                                               QS036900
      XGRID(ZN2M1,1)=XGRID(1,1)                                              QS036910
      XGRID(ZNO,1)=-XGRID(1,1)                                               QS036920
      DO  1 I=1,N2ZM11                                                       QS036930
      DO 1 J=1,ENOPLS                                                        QS036940
      SIG=1.                                                                 QS036950
      IF(J.GT.ENO) SIG=-1.                                                   QS036960
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      ZGRID=(XGRID(I,J)+AI*YGRID(I,J)*SIG)                              QS036970
      AHTAN=CEXP((ZGRID      )/2.)-CEXP(-(ZGRID     )/2.)               QS036980
      AHTAN2=CEXP((ZGRID      )/2.)+CEXP(-(ZGRID     )/2.)              QS036990
      AHYPT=AHTAN/AHTAN2                                                QS037000
      ZCMX=ALAMDA*AHYPT                                                 QS037010
      WCMX=ZCMX+CSQRT(ZCMX-1.)*CSQRT(ZCMX+1.)                           QS037020
      IF(R.LT.1.1.AND.YGRID(I,J).EQ.0.)WCMX=CMPLX(REAL(WCMX),0.)        QS037030
      IF(ABS(ABS(REAL(WCMX))-R).LT.1.E-07)                              QS037040
     1AQT1=CMPLX(SIGN(25.,XGRID(I,J)),0.)                               QS037050
      IF(ABS(ABS(REAL(WCMX))-R).GE.1.E-07)                              QS037060
     1AQT1=(CLOG(READK*WCMX+1.)-CLOG(READK*WCMX-1.))                    QS037070
      IF(ZET(I) .LT.0.)AQT1=AQT1-2.*AI*PI                               QS037080
                                                                        QS037090
C      ADD STAGGER TERM                                                 QS037100
                                                                        QS037110
      AQT1=AQT1*CEXP(-AI*STAG)                                          QS037120
      AQT2=(CLOG(WCMX+READK)-CLOG(WCMX-READK))*CEXP(AI*STAG)            QS037130
                                                                        QS037140
C      CORRECT FOR PROPER SOLIDITY COEFFICIENT AND ASSEMBLE X+IY        QS037150
      ZCMX=(AQT1+AQT2)/(2.*PI*SOLID2)*CHORD                             QS037160
      XGRID(I,J)= REAL(ZCMX)+SIN(STAG)/2./SOLID2 *CHORD                 QS037170
      YGRID(I,J)= SIG*(AIMAG(ZCMX)+COS(STAG)/2./SOLID2 *CHORD)          QS037180
      YGRID(ZN2M1,J)=YGRID(1,J)                                         QS037190
1     XGRID(ZN2M1,J)=XGRID(1,J)                                         QS037200
      RETURN                                                            QS037210
      END                                                               QS037220
      SUBROUTINE ALTERP(COVERS,STAG,ALFA,R)                             QS037230
                                                                        QS037240
C      PERFORMS DOUBLE LINEAR INTERPOLATION ON STAGGER ANGLE AND SOLIDITQS037250
C     Y TO OBTAIN                                                       QS037260
C      POSITIONS OF VORTEX SINGULARITIES IN THE CONFORMAL PLANE.        QS037270
                                                                        QS037280
C      SOURCE, HAWTHORNE (LISTED AS REF. 4 OF REF. 2. OF USERS MANUAL)  QS037290
                                                                        QS037300
                                                                        QS037310
                                                                        QS037320
      DIMENSION CSTAB(25,25),GAMTAB(25),RTAB(25),ISTAR(2)               QS037330
                                                                        QS037340
C      TABULATED VALUES FROM THE RANGE OF FIGS B,5C AND B,5D (PP.30,31) QS037350
C     OF HAWTHORNE                                                      QS037360
      DATA RTAB,GAMTAB/1.001,                                           QS037370
     1                    1.005,1.01,1.02,1.03,1.04,1.05,1.1,1.2,1.3,1.4QS037380
     1,1.5,1.6,1.7,1.8,1.9,2.,2.25,2.5,2.75,3.,3.5,4.,4.5,5.,0.,5.,10., QS037390
     115.,20.,25.,30.,35.,40.,45.,50.,55.,60.,65.,70.,75.,80.,85.,91.,  QS037400
     195.,100.,4*150./                                                  QS037410
      PI=3.14159265                                                     QS037420
      DO 1 J=1,19                                                       QS037430
      G=GAMTAB(J)*PI/180.                                               QS037440
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      DO 1 I=1,25                                                       QS037450
      RD=RTAB(I)                                                        QS037460
                                                                        QS037470
C       EQNS. FROM FIGS B,5C AND D                                      QS037480
                                                                        QS037490
      AL=ATAN(TAN(G)*(RD*RD-1.)/(RD*RD+1.))                             QS037500
1     CSTAB(I,J)=1./PI*(COS(G)*ALOG((RD*RD+2.*RD*COS(AL)+1.)/(RD*RD-2.  QS037510
     1*RD*COS(AL)+1.))+2.*SIN( G)*ATAN(2.*RD*SIN(AL)/(RD*RD-1.)))       QS037520
                                                                        QS037530
                                                                        QS037540
      STAGG=STAG*180./PI                                                QS037550
      DO 20 J=1,25                                                      QS037560
      IF(STAGG.LE.GAMTAB(J))GOTO21                                      QS037570
20    CONTINUE                                                          QS037580
      J=25                                                              QS037590
21    JSTAR=J                                                           QS037600
      JSM1=J-1                                                          QS037610
      DO 40 J=JSM1,JSTAR                                                QS037620
      J1=J-JSM1+1                                                       QS037630
      DO 30 I=1,25                                                      QS037640
      IF(COVERS.GE.CSTAB(I,J))GOTO31                                    QS037650
30    CONTINUE                                                          QS037660
      I=25                                                              QS037670
31    ISTAR(J1)=I                                                       QS037680
40    CONTINUE                                                          QS037690
      ISM1=ISTAR(2)-1                                                   QS037700
      ISSM1=ISTAR(1)-1                                                  QS037710
      IS=ISTAR(2)                                                       QS037720
      ISS=ISTAR(1)                                                      QS037730
      R1=RTAB(ISS)+(RTAB(ISSM1)-RTAB(ISS))*(COVERS-CSTAB(ISS,JSM1))/    QS037740
     1(CSTAB(ISSM1,JSM1)-CSTAB(ISS,JSM1))                               QS037750
      R2=RTAB(IS)+(RTAB(ISM1)-RTAB(IS))*(COVERS -CSTAB(IS,JSTAR))/      QS037760
     1(CSTAB(ISM1,JSTAR)-CSTAB(IS,JSTAR))                               QS037770
      R=R1+(R2-R1)*(STAGG-GAMTAB(JSM1))/(GAMTAB(JSTAR)-GAMTAB(JSM1))    QS037780
      IF(COVERS.GT.5.)R=1.0001                                          QS037790
      ALFA=ATAN(TAN(STAG)*(R*R-1.)/(R*R+1.))                            QS037800
      RETURN                                                            QS037810
      END                                                               QS037820
      FUNCTION FUDS(E,Z,SCK)                                            QS037830
                                                                        QS037840
C       CALCULATES FUNCTION  'T' IN EQN. 1., REF. 2. OF USER MANUAL     QS037850
                                                                        QS037860
                                                                        QS037870
      COMMON/GEOM/ DUMP(19),G                                           QS037880
      COMMON/FUNCOS/S,C,D,SN,CN,DN                                      QS037890
      CALL JELF(S,C,D,E,SCK)                                            QS037900
      CALL JELF(SN,CN,DN,Z,G)                                           QS037910
      B=S*DN*S*DN+(C*D*SN*CN)**2                                        QS037920
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      FUDS = SQRT(B)                                                    QS037930
      RETURN                                                            QS037940
      END                                                               QS037950
      FUNCTION OWOW(SCK)                                                QS037960
                                                                        QS037970
C      CALCULATES FUNCTION 'OMEGA' IN EQN. 1., REF. 2 OF USERS MANUAL   QS037980
                                                                        QS037990
                                                                        QS038000
      COMMON/FUNCOS/S,C,D,SN,CN,DN                                      QS038010
      IF(S.EQ.0.)S=1.E-20                                               QS038020
      B= C*D*SN*CN/S/DN                                                 QS038030
      OWOW = ATAN(B)                                                    QS038040
      RETURN                                                            QS038050
      END                                                               QS038060
      FUNCTION BADZAC(SCK)                                              QS038070
                                                                        QS038080
C      CALCULATES FUNCTIUON 'GAMMA' IN EQN. 1., REF. 2 OF USERS MANUAL  QS038090
                                                                        QS038100
                                                                        QS038110
      COMMON/FUNCOS/S,C,D,SN,CN,DN                                      QS038120
      BADZAC = CN*CN+(1.-SCK)*S*S*SN*SN                                 QS038130
      RETURN                                                            QS038140
      END                                                               QS038150
      SUBROUTINE JELF(SN,CN,DN,X,SCK)                                   QS038160
                                                                        QS038170
C      COMPUTES JACOBIAN ELLIPTIC FCNS SN,CN,DN                         QS038180
                                                                        QS038190
C      IF X IS GIVEN AS THE ELLIPTIC INTEGRAL OF THE FIRST KIND WITH MODQS038200
C     ULUS K                                                            QS038210
C      FROM ZERO TO SIN(PHI)  WITH  0<PHI<PI/2, THEN                    QS038220
C              SCK = 1-K*K                                              QS038230
C              SN(X,K)=SIN(PHI)                                         QS038240
C              CN(X,K)=COS(PHI)                                         QS038250
C   AND        DN(X,K)=SQRT(1.-K*K*SIN(PHI)**2)                         QS038260
                                                                        QS038270
                                                                        QS038280
                                                                        QS038290
      DIMENSION ARI(12),GEO(12)                                         QS038300
      CM=SCK                                                            QS038310
      Y=X                                                               QS038320
      IF(SCK) 3,1,4                                                     QS038330
1     D=EXP(X)                                                          QS038340
      A=1./D                                                            QS038350
      B=A+D                                                             QS038360
      CN=2./B                                                           QS038370
      DN=CN                                                             QS038380
      SN=TANH(X)                                                        QS038390
2     RETURN                                                            QS038400
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3     D=1.-SCK                                                          QS038410
      CM=-SCK/D                                                         QS038420
      D=SQRT(D)                                                         QS038430
      Y=D*X                                                             QS038440
4     A=1.                                                              QS038450
      DN=1.                                                             QS038460
      DO 6 I=1,12                                                       QS038470
      L=I                                                               QS038480
      ARI(I)=A                                                          QS038490
      CM=SQRT(CM)                                                       QS038500
      GEO(I)=CM                                                         QS038510
      C=(A+CM)*.5                                                       QS038520
      IF(ABS(A-CM)-1.E-4*A)7,7,5                                        QS038530
5     CM=A*CM                                                           QS038540
6     A=C                                                               QS038550
7     Y=C*Y                                                             QS038560
      SN=SIN(Y)                                                         QS038570
      CN=COS(Y)                                                         QS038580
      IF(SN)8,13,8                                                      QS038590
8     A=CN/SN                                                           QS038600
      C=A*C                                                             QS038610
      DO 9 I=1,L                                                        QS038620
      K=L-I+1                                                           QS038630
      B=ARI(K)                                                          QS038640
      A=C*A                                                             QS038650
      C=DN*C                                                            QS038660
      DN=(GEO(K)+A)/(B+A)                                               QS038670
9     A=C/B                                                             QS038680
      A=1./SQRT(C*C+1.)                                                 QS038690
      IF(SN)10,11,11                                                    QS038700
10    SN=-A                                                             QS038710
      GOTO 12                                                           QS038720
11    SN=A                                                              QS038730
12    CN=C*SN                                                           QS038740
13    IF(SCK)14,2,2                                                     QS038750
14    A=DN                                                              QS038760
      DN=CN                                                             QS038770
      CN=A                                                              QS038780
      SN=SN/D                                                           QS038790
      RETURN                                                            QS038800
      END                                                               QS038810
      SUBROUTINE XYCALC(KSTART,K2,Z,X,Y)                                QS038820
C           -- XYCALC --                                                QS038830
C.....GENERATES DATA FILES FOR ON-BODY POINTS.                           QS038840
                                                                        QS038850
      INTEGER SGEN                                                      QS038860
      REAL                          C(400),S(400),SP(400)               QS038870
      COMPLEX Z(400),DZ(400),D2Z,ZZ,FZTRP,DZTRP                         QS038880
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      LOGICAL THIN,EVEN,SPGEN,DONE                                      QS038890
      COMMON /MAN/ DELSMX,PIO2,DELS1,IHUB                               QS038900
      DIMENSION X(400),Y(400)                                           QS038910
      COMMON /SPGENC/      A,DSMAX,RMAX,THIN,B,TMIN,DSEND               QS038920
      DATA NSMAX,EMPTY/400,1.0E20/                                      QS038930
                                                                        QS038940
C.....INITIALIZE PROGRAM.                                               QS038950
      S1=0.0                                                            QS038960
      NMAX=400                                                          QS038970
      DSMAX=DELSMX                                                      QS038980
      DELS1=DELSMX                                                      QS038990
      THIN=.FALSE.                                                      QS039000
      RMAX=1.2                                                          QS039010
      DSEND=DSMAX                                                       QS039020
      DONE=.FALSE.                                                      QS039030
      EVEN=.FALSE.                                                      QS039040
      B=0.3                                                             QS039050
      TMIN=0.1                                                          QS039060
      NFIN=0                                                            QS039070
      NSP=0                                                             QS039080
                                                                        QS039090
C.....INPUT BODY POINTS AND BODY TYPE.                                  QS039100
      DO 25 I=1,NSMAX                                                   QS039110
      IF (REAL(Z(I)).EQ.EMPTY) GO TO 30                                 QS039120
25    NS=I                                                              QS039130
30    S(1)=S1                                                           QS039140
      IBAD=SGEN(S,Z,NS)                                                 QS039150
C     WRITE(6,140)                                                      QS039160
140   FORMAT(31H0THE FOLLOWING IS S FROM XYCALC///)                     QS039170
C     WRITE(6,*)S                                                       QS039180
C     WRITE(6,145)                                                      QS039190
145   FORMAT(31H0THE FOLLOWING IS Z FROM XYCALC///)                     QS039200
C     WRITE(6,*)Z                                                       QS039210
C     WRITE(6,150)                                                      QS039220
150   FORMAT(32H0THE FOLLOWING IS NS FROM XYCALC///)                    QS039230
C     WRITE(6,*)NS                                                      QS039240
      IF (IBAD.NE.0) WRITE (6,125)IBAD                                  QS039250
                                                                        QS039260
C.....SET UP DERIVATIVES + CURVATURES.                                  QS039270
      DO 35 I=1,NS                                                      QS039280
35    DZ(I)=DZTRP(S,Z,S(I),NS)                                          QS039290
      DO 40 I=1,NS                                                      QS039300
      D2Z=DZTRP(S,DZ,S(I),NS)                                           QS039310
40    C(I)=AIMAG(CONJG(DZ(I))*D2Z)/CABS(DZ(I))**3                       QS039320
                                                                        QS039330
C.....INPUT AUXILLIARY (CONTROL) DATA.                                  QS039340
      IF (NFIN.EQ.0) NFIN=NS                                            QS039350
      SFIN=S(NFIN)                                                      QS039360
```

```
      DSMAX=AMAX1(DSMAX,DSEND)                                            QS039370
                                                                          QS039380
C.....GENERATE BODY POINTS ON A SEGMENT.                                  QS039390
      IF (.NOT.SPGEN(S,Z,C,NS,SP,NSP,SFIN,NMAX)) GO TO 130                QS039400
                                                                          QS039410
                                                                          QS039420
C.....OUTPUT RESULTING ON-BODY POINTS.                                    QS039430
85    DO 90 I=1,NSP                                                       QS039440
      IBY=KSTART+I-1                                                      QS039450
      ZZ=FZTRP(S,Z,SP(I),NS)                                              QS039460
C     DZ(I)=DZTRP(S,Z,SP(I),NS)                                           QS039470
C     D2Z=DZTRP(S,DZ,SP(I),NS)                                            QS039480
C     C(I)= AIMAG(CONJG(DZ(I))*D2Z)/CABS(DZ(I))**3                        QS039490
      X(IBY)=REAL(ZZ)                                                     QS039500
90    Y(IBY)=AIMAG(ZZ)                                                    QS039510
      K1=KSTART                                                           QS039520
      K2=NSP+KSTART-1                                                     QS039530
120   RETURN                                                              QS039540
C.....ERROR MESSAGES.                                                     QS039550
125   FORMAT(21H SGEN FAILED.  IBAD= ,I3)                                 QS039560
130   WRITE (6,135)                                                       QS039570
135   FORMAT(34H SPGEN UNABLE TO COMPLETE SEGMENT )                       QS039580
      STOP                                                                QS039590
      END                                                                 QS039600
      INTEGER FUNCTION SGEN(S,F,NS)                                       QS039610
      REAL S(400)                                                         QS039620
      COMPLEX F(400),DZTRP                                                QS039630
      DATA MAX,N,FN,TEST/4,10,10.0,0.01/                                  QS039640
      DO 10 I=2,NS                                                        QS039650
10    S(I)=S(I-1)+CABS(F(I)-F(I-1))                                       QS039660
      DO 30 K=1,MAX                                                       QS039670
      SGEN=0                                                              QS039680
      DO 25 I=2,NS                                                        QS039690
      DS=S(I)-S(I-1)                                                      QS039700
      DARG=DS/FN                                                          QS039710
      ARGO=S(I-1)-DARG/2.0                                                QS039720
      SUM=0.0                                                             QS039730
      DO 15 J=1,N                                                         QS039740
      ARG=ARGO+FLOAT(J)*DARG                                              QS039750
      TVQQ=CABS(DZTRP(S,F,ARG,NS))-1.0                                    QS039760
15    SUM=SUM+TVQQ                                                        QS039770
      SUM=SUM/FN                                                          QS039780
      ERROR=ABS(SUM)                                                      QS039790
C     WRITE(6,19)                                                         QS039800
19    FORMAT(42H0THE FOLLOWING IS TVQQ,SUM,ERROR FROM SGEN)               QS039810
C     WRITE(6,*)TVQQ,SUM,ERROR                                            QS039820
      DS=DS*SUM                                                           QS039830
      DO 20 J=1,NS                                                        QS039840
```

```
20    S(J)=S(J)+DS                                                      QS039850
      IF(ERROR.GT.TEST.AND.SGEN.EQ.0)SGEN=I                             QS039860
25    CONTINUE                                                          QS039870
      IF(SGEN.EQ.0)RETURN                                               QS039880
30    CONTINUE                                                          QS039890
      RETURN                                                            QS039900
      END                                                               QS039910
      LOGICAL FUNCTION SPGEN (S,Z,C,NS,SP,NSP,SFIN,NMAX)                QS039920
C.....GENERATES TABLE SP HAVING VALUES OF PARAMETER S AS WIDELY SPACED  QS039930
C     AS POSSIBLE AND YET SATISFYING THE FOLLOWING CONDITIONS ON DS:    QS039940
C        1   NSP .LE. NMAX                                              QS039950
C        2   DS  .LE. A/C(S)    (C=CURVATURE)                           QS039960
C        3   DS  .LE. DSMAX                                             QS039970
C        4A  DS(I) .LE. DS(I-1)*RMAX                                    QS039980
C        4B  DS(I) .GE. DS(I-1)/RMAX                                    QS039990
C     FOR THIN SECTIONS, AN ADDITIONAL CONDITION IS:                    QS040000
C            DS  .LE. B*TLOC    (TLOC=LOCAL THICHNESS)                  QS040010
C.....SPGEN = .TRUE. IF ALL CONDITIONS HAVE BEEN SATISFIED.             QS040020
                                                                        QS040030
      REAL S(400),C(400),SP(400)                                        QS040040
      COMPLEX Z(400),FZTRP                                              QS040050
      LOGICAL THIN,FIN                                                  QS040060
      COMMON /SPGENC/      A,DSMAX,RMAX,THIN,B,TMIN,DSEND               QS040070
      COMMON /MAN/ DELSMX,PIO2,DELS1,IHUB                               QS040080
      DATA ONE,CMIN/1.0001,1.0E-6/                                      QS040090
                                                                        QS040100
C.....INITIALIZATION SECTION.                                           QS040110
      SPGEN=.FALSE.                                                     QS040120
      J1=MAX0(NSP,2)+1                                                  QS040130
      IF (NSP.GT.1) GO TO 15                                            QS040140
      IF (NSP.LT.1) SP(1)=S(1)                                          QS040150
      DS1=      DELS1                                                   QS040160
10    SP(2)=SP(1)+DS1                                                   QS040170
C     WRITE(6,51)                                                       QS040180
51    FORMAT(30H0THE FOLLOWING IS S FROM SPGEN//////)                   QS040190
C     WRITE(6,*)S                                                       QS040200
C     WRITE(6,52)                                                       QS040210
52    FORMAT(30H0THE FOLLOWING IS C FROM SPGEN///////)                  QS040220
C     WRITE(6,*)C                                                       QS040230
C     WRITE(6,53)                                                       QS040240
53    FORMAT(33H0THE FOLLOWING IS SBAR FROM SPGEN//////)                QS040250
C     WRITE(6,*)SBAR                                                    QS040260
C     WRITE(6,54)                                                       QS040270
54    FORMAT(31H0THE FOLLOWING IS NS FROM SPGEN////////)                QS040280
C     WRITE(6,*)NS                                                      QS040290
C.....BEGIN MAIN LOOP.                                                  QS040300
15    DO 45 J=J1,NMAX                                                   QS040310
      L=J                                                               QS040320
```

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20    I=L                                                               QS040330
25    DSLAST=SP(I-1)-SP(I-2)                                            QS040340
      SBAR=SP(I-1)+DSLAST/2.0                                           QS040350
      CA=AMAX1(CMIN,ABS(FNTRP(S,C,SBAR,NS)))                            QS040360
      DSLIM=AMIN1(DS1   ,DSLAST*RMAX)                                   QS040370
      IF (.NOT.THIN) GO TO 30                                           QS040380
      TLOC=CABS(FZTRP(S,Z,SBAR,NS)-FZTRP(S,Z,S(NS)-SBAR,NS))            QS040390
      DSLIM=AMIN1(DSLIM,B*AMAX1(TLOC,TMIN))                             QS040400
30    DSFIN=SFIN-SP(I-1)                                                QS040410
      NEVEN=DSFIN/DSLIM/ONE+1.0                                         QS040420
      DSEVEN=DSFIN/FLOAT(NEVEN)                                         QS040430
      DS=AMIN1(A/CA,DSEVEN)                                             QS040440
      IF (I.NE.J) DS=AMIN1(DS,DSLAST/RMAX)                              QS040450
                                                                        QS040460
C.....CALCULATED VALUE OF DS SATISFIES CONDITIONS 2 THRU 4A.TEST FOR 4B.QS040470
      IF (DS.GE.DSLAST/RMAX) GO TO 40                                   QS040480
                                                                        QS040490
C.....IF CONDITION 4B IS NOT SATISFIED, RE-DO EARLIER INTERVALS         QS040500
C.....USING SMALLER VALUES OF DS.  IF RE-DOING ALL INTERVALS WON'T      QS040510
C.....WORK, START OVER USING SMALLER STARTING VALUE OF DS (DS1).        QS040520
35    L=L-1                                                             QS040530
      IF (L.GE.J1) GO TO 20                                             QS040540
      IF (NSP.GT.1) RETURN                                              QS040550
      DS1=DS1/RMAX                                                      QS040560
      GO TO 10                                                          QS040570
                                                                        QS040580
C.....IF CONDITIONS 2 THRU 4B ARE SATISFIED, TEST FOR FINISH.           QS040590
40    SP(I)=SP(I-1)+DS                                                  QS040600
      FIN=SFIN/SP(I).LE.ONE                                             QS040610
      IF (FIN.AND.DS.GT.DSEND) GO TO 35                                 QS040620
      IF (FIN) GO TO 50                                                 QS040630
      IF (I.GE.J) GO TO 45                                              QS040640
      I=I+1                                                             QS040650
      GO TO 25                                                          QS040660
45    CONTINUE                                                          QS040670
C.....SPGEN =.FALSE. IF CONDITION 1 CANNOT BE SATISFIED.                QS040680
      RETURN                                                            QS040690
                                                                        QS040700
C.....IF CONDITIONS ARE SATISFIED, UPDATE NSP.                          QS040710
50    NSP=I                                                             QS040720
      DELS1=DS                                                          QS040730
      SPGEN=.TRUE.                                                      QS040740
      RETURN                                                            QS040750
      END                                                               QS040760
      COMPLEX FUNCTION DZTRP (A,F,X,NA)                                 QS040770
C.....COMPLEX DERIVATIVE EVALUATION FOR DOUBLE 3-POINT INTERPOLATION.   QS040780
      COMPLEX F(400)                                                    QS040790
      REAL A(400)                                                       QS040800
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      COMMON /NTRPC3/ I1,I2,C(4)                                               QS040810
C.....FIRST EVALUATE FUNCTION COEFFICIENTS.                                    QS040820
      CALL FNTRPA (A,X,NA)                                                     QS040830
      CALL DNTRPC                                                              QS040840
C.....THEN EVALUATE FUNCTION VALUE.                                            QS040850
C     GO TO 10                                                                 QS040860
C     ENTRY DZTRP1 (F)                                                         QS040870
C     DZTRP1=0.                                                                QS040880
10    DZTRP=0.0                                                                QS040890
      J=0                                                                      QS040900
      DO 1 I=I1,I2                                                             QS040910
      J=J+1                                                                    QS040920
1     DZTRP=DZTRP+C(J)*F(I)                                                    QS040930
      RETURN                                                                   QS040940
      END                                                                      QS040950
      COMPLEX FUNCTION FZTRP (A,F,X,NA)                                        QS040960
C.....COMPLEX FUNCTION EVALUATION BY DOUBLE 3-POINT INTERPOLATION.             QS040970
      COMPLEX F(400)                                                           QS040980
      REAL A(400)                                                              QS040990
      COMMON /NTRPC2/ I1,I2,C(4)                                               QS041000
C.....FIRST EVALUATE FUNCTION COEFFICIENTS.                                    QS041010
      CALL FNTRPA (A,X,NA)                                                     QS041020
      CALL FNTRPC                                                              QS041030
C.....THEN EVALUATE FUNCTION VALUE.                                            QS041040
C     GO TO 10                                                                 QS041050
C     ENTRY FZTRP1 (F)                                                         QS041060
C     FZTRP1=0.                                                                QS041070
10    FZTRP=0.0                                                                QS041080
      J=0                                                                      QS041090
      DO 1 I=I1,I2                                                             QS041100
      J=J+1                                                                    QS041110
1     FZTRP=FZTRP+C(J)*F(I)                                                    QS041120
      RETURN                                                                   QS041130
      END                                                                      QS041140
      FUNCTION FNTRP (A,F,X,NA)                                                QS041150
C.....FUNCTION EVALUATION FOR DOUBLE 3-POINT INTERPOLATION.                    QS041160
      REAL F(400),A(400)                                                       QS041170
      COMMON /NTRPC2/ I1,I2,C(4)                                               QS041180
C.....FIRST EVALUATE FUNCTION COEFFICIENTS.                                    QS041190
      CALL FNTRPA (A,X,NA)                                                     QS041200
      CALL FNTRPC                                                              QS041210
C.....THEN EVALUATE FUNCTION VALUE.                                            QS041220
C     GO TO 5                                                                  QS041230
C     ENTRY FNTRP1 (F)                                                         QS041240
C     FNTRP1=0.                                                                QS041250
5     FNTRP=0.0                                                                QS041260
      J=0                                                                      QS041270
      DO 10 I=I1,I2                                                            QS041280
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      J=J+1                                                             QS041290
10    FNTRP=FNTRP+C(J)*F(I)                                             QS041300
      RETURN                                                            QS041310
      END                                                               QS041320
      SUBROUTINE DNTRPC                                                 QS041330
C.....CALCULATION OF C COEFFICIENTS FOR DERIVATIVES OF DOUBLE           QS041340
C.....3-POINT INTERPOLATION.                                            QS041350
      COMMON /NTRPC1/ L,I,A11,A12,A13,A14,A22,A23,A24,A33,A34,A44       QS041360
      COMMON /NTRPC3/ I1,I2,C1,C2,C3,C4                                 QS041370
      IF (L.LE.1) GO TO 13                                              QS041380
      IF (L-3) 12,11,10                                                 QS041390
C.....FOR DOUBLE 3-POINT INTERPOLATION.                                 QS041400
10    C1=+(A22+A33+A22)/A23*A33/A12/A13                                 QS041410
      C4=-(A33+A22+A33)/A23*A22/A34/A24                                 QS041420
      P=A23*A23                                                         QS041430
      C2=-((A11+A33+A11)*A33/A12+(A33*A44+A22*A44+A22*A33)/A24)/P       QS041440
      C3=+((A44+A22+A44)*A22/A34+(A22*A11+A33*A11+A33*A22)/A13)/P       QS041450
      GO TO 14                                                          QS041460
C.....FOR SIMPLE 3-POINT INTERPOLATION.                                 QS041470
11    C1=+(A33+A22)/A12/A13                                             QS041480
      C2=-(A33+A11)/A12/A23                                             QS041490
      C3=+(A22+A11)/A13/A23                                             QS041500
      GO TO 14                                                          QS041510
C.....FOR 2-POINT INTERPOLATION.                                        QS041520
12    C1=1.0/A12                                                        QS041530
      C2=-C1                                                            QS041540
      GO TO 14                                                          QS041550
C.....ONLY ONE TABLE VALUE GIVEN.                                       QS041560
13    C1=0.0                                                            QS041570
14    I1=I                                                              QS041580
      I2=I+L-1                                                          QS041590
      RETURN                                                            QS041600
      END                                                               QS041610
      SUBROUTINE FNTRPA(A,X,NA)                                         QS041620
C.....COMMON SUBROUTINE EVALUATES A COEFFICIENTS IN DOUBLE              QS041630
C.....3-POINT INTERPOLATIONS.                                           QS041640
C       L=NO. OF POINTS IN THE FIT                                      QS041650
C       I=INDEX TO FIRST POINT                                          QS041660
      REAL A(400)                                                       QS041670
      COMMON /NTRPC1/ L,I,A11,A12,A13,A14,A22,A23,A24,A33,A34,A44       QS041680
C.....GET I AND L BY TABLE LOOK-UP.                                     QS041690
      L=LIMIT (1,NA,3)                                                  QS041700
      M=MAX0(1,NA-2)                                                    QS041710
      CALL TLU (A,X,NA,J)                                               QS041720
      IF (J.EQ.LIMIT(2,J,M)) L=4                                        QS041730
      I=LIMIT(1,J-1,M)                                                  QS041740
C.....CALCULATE A-ARRAY.                                                QS041750
      A11=A(I)                                                          QS041760
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      A22=A(I+1)                                                        QS041770
      A33=A(I+2)                                                        QS041780
      IF (L.NE.4) IF (L-2) 20,15,10                                     QS041790
      A44=A(I+3)                                                        QS041800
      A14=A11-A44                                                       QS041810
      A24=A22-A44                                                       QS041820
      A34=A33-A44                                                       QS041830
      A44=X-A44                                                         QS041840
10    A13=A11-A33                                                       QS041850
      A23=A22-A33                                                       QS041860
      A33=X-A33                                                         QS041870
15    A12=A11-A22                                                       QS041880
      A22=X-A22                                                         QS041890
      A11=X-A11                                                         QS041900
20    RETURN                                                            QS041910
      END                                                               QS041920
      SUBROUTINE FNTRPC                                                 QS041930
C.....CALCULATION OF C COEFFICIENTS FOR FUNCTION VALUES BY DOUBLE       QS041940
C.....3-POINT INTERPOLATION.                                            QS041950
      COMMON /NTRPC1/L,I,A11,A12,A13,A14,A22,A23,A24,A33,A34,A44        QS041960
      COMMON /NTRPC2/ I1,I2,C1,C2,C3,C4                                 QS041970
      IF (L.LE.1) GO TO 25                                              QS041980
      IF (L-3) 20,15,10                                                 QS041990
C.....FOR DOUBLE 3-POINT INTERPOLATION.                                 QS042000
10    C1=+A33/A23*A22/A12*A33/A13                                       QS042010
      C4=-A22/A23*A33/A34*A22/A24                                       QS042020
      P2=A33/A23*A11/A23                                                QS042030
      P3=A22/A23*A44/A23                                                QS042040
      C2=-A33*(P2/A12+P3/A24)                                           QS042050
      C3=+A22*(P3/A34+P2/A13)                                           QS042060
      GO TO 30                                                          QS042070
C.....FOR SIMPLE 3-POINT INTERPOLATION.                                 QS042080
15    C1=+A22/A12*A33/A13                                               QS042090
      C2=-A11/A12*A33/A23                                               QS042100
      C3=+A11/A13*A22/A23                                               QS042110
      GO TO 30                                                          QS042120
C.....FOR 2-POINT INTERPOLATION.                                        QS042130
20    C1=+A22/A12                                                       QS042140
      C2=-A11/A12                                                       QS042150
      GO TO 30                                                          QS042160
C.....ONLY ONE TABLE VALUE GIVEN.                                       QS042170
25    C1=1.0                                                            QS042180
30    I1=I                                                              QS042190
      I2=I+L-1                                                          QS042200
      RETURN                                                            QS042210
      END                                                               QS042220
      SUBROUTINE TLU (TABLE,ARG,N,I)                                    QS042230
C.....TABLE LOOK UP:  FINDS I SUCH THAT                                 QS042240
```

```
C     ARG.GE.TABLE(I).AND.ARG.LT.TABLE(I+1)                             QS042250
C       IF I=0, ARG.LT.TABLE(1)                                         QS042260
C       IF I=N, ARG.GE.TABLE(N)                                         QS042270
      REAL TABLE(400)                                                   QS042280
      I=LIMIT(1,I,N)                                                    QS042290
      IF (ARG.GE.TABLE(I)) GO TO 15                                     QS042300
C.....DESCEND IN TABLE.                                                  QS042310
10    I=I-1                                                             QS042320
      IF (I.LE.0) RETURN                                                QS042330
      IF (ARG.GE.TABLE(I)) RETURN  .                                    QS042340
      GO TO 10                                                          QS042350
C.....ASCEND IN TABLE.                                                   QS042360
15    IF (I.GE.N) RETURN                                                QS042370
      IF (ARG.LT.TABLE(I+1)) RETURN                                     QS042380
      I=I+1                                                             QS042390
      GO TO 15                                                          QS042400
      END                                                               QS042410
      FUNCTION LIMIT (I,J,K)                                            QS042420
C.....INTEGER FUNCTION LIMITS J BETWEEN I AND K.                         QS042430
      LIMIT=I                                                           QS042440
      IF (J.LT.LIMIT) RETURN                                            QS042450
      LIMIT=K                                                           QS042460
      IF (J.GT.LIMIT) RETURN                                            QS042470
      LIMIT=J                                                           QS042480
      RETURN                                                            QS042490
      END                                                               QS042500
      LOGICAL FUNCTION XNTRP (A,F,FO,NA,X)                              QS042510
C.....INVERSE FUNCTION FOR DOUBLE 3-POINT INTERPOLATION.                 QS042520
                                                                        QS042530
C     GIVEN TABLES A AND F (EACH OF LENGTH NA), THE VALUE OF X IS       QS042540
C     FOUND FOR WHICH FNTRP (A,F,X,NA)=FO.  ONLY SOLUTIONS LARGER       QS042550
C     THAN THE ENTRY VALUE OF X ARE CONSIDERED; ONLY THE SMALLEST       QS042560
C     OF THESE IS RETURNED.  IF NO SOLUTION IS FOUND, XNTRP=.FALSE.     QS042570
C     AND X IS LEFT UNALTERED.                                          QS042580
                                                                        QS042590
      REAL A(400),F(400),C(4),R(3)                                      QS042600
      INTEGER II(3),REALX,RCMPLX,ICMPLX,TYPE                            QS042610
      LOGICAL LAST,SIZE                                                 QS042620
      COMMON /NTRPC1/ L,I,EXTRA(10)                                     QS042630
      COMMON /NTRPC5/ M,B(4,4)                                          QS042640
      DATA REALX,RCMPLX,ICMPLX,EPSLON/0,1,2,1.0E-5/                     QS042650
      COMPLEX FZ(400)                                                   QS042660
      TYPE=REALX                                                        QS042670
      GO TO 100                                                         QS042680
                                                                        QS042690
C.....ALTERNATE ENTRIES FOR COMPLEX TYPE FUNCTION TABLES:                QS042700
                                                                        QS042710
C.....RZTRP IS USED TO GET X FOR WHICH REAL(FZTRP(A,F,X,NA))=FO.         QS042720
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      ENTRY RZTRP (A,FZ,FO,NA,X)                                        QS042730
      RZTRP=0.                                                          QS042740
C.... COMPLEX FZ(NA) THIS WAS MOVED UP TO COMPILE PROPERLY ON NPS 370   QS042750
      TYPE=RCMPLX                                                       QS042760
      GO TO 100                                                         QS042770
                                                                        QS042780
C.....IZTRP IS USED TO GET X FOR WHICH AIMAG(FZTRP(A,F,X,NA))=FO.       QS042790
      ENTRY IZTRP (A,FZ,FO,NA,X)                                        QS042800
      IZTRP=0.                                                          QS042810
      TYPE=ICMPLX                                                       QS042820
                                                                        QS042830
C.....INITIALIZATION.                                                   QS042840
100   XIN=X                                                             QS042850
      XMAX=XIN                                                          QS042860
      DX=0.0                                                            QS042870
                                                                        QS042880
C.....CALCULATE POLYNOMIAL COEFFICIENTS.                                QS042890
1     XMIN=AMAX1(XIN+DX,XMAX-DX)                                        QS042900
      CALL BNTRP (A,XMAX,NA)                                            QS042910
      LAST=M.GE.NA-1                                                    QS042920
      IF (LAST) GO TO 2                                                 QS042930
      MAX=M+L-3                                                         QS042940
      XMAX=A(MAX)                                                       QS042950
2     DO 3 J=1,L                                                        QS042960
      C(J)=0.0                                                          QS042970
      DO 3 N=1,L                                                        QS042980
      IN=I+N-1                                                          QS042990
      IF (TYPE.EQ.REALX) C(J)=C(J)+B(N,J)*F(IN)                         QS043000
      IF (TYPE.EQ.RCMPLX) C(J)=C(J)+B(N,J)*REAL(FZ(IN))                 QS043010
      IF (TYPE.EQ.ICMPLX) C(J)=C(J)+B(N,J)*AIMAG(FZ(IN))                QS043020
3     CONTINUE                                                          QS043030
      C(1)=C(1)-FO                                                      QS043040
      IF(L.EQ.4.AND.ABS(C(L)).LT.1.E-04)L=3                             QS043050
      LL=L                                                              QS043060
4     IF (LL.LT.2) GO TO 8                                              QS043070
      IF (C(LL).NE.0.0) GO TO 5                                         QS043080
      LL=LL-1                                                           QS043090
      GO TO 4                                                           QS043100
                                                                        QS043110
C.....GET ROOTS OF POLYNOMIAL.                                          QS043120
5     NR=1                                                              QS043130
      IF (LL.EQ.2) R(1)=-C(1)/C(2)                                      QS043140
      IF (LL.EQ.3) NR=NRRTS2(C,R)                                       QS043150
      IF (LL.EQ.4) NR=NRRTS3(C,R)                                       QS043160
                                                                        QS043170
C.....TEST ROOTS OF POLYNOMIAL.                                         QS043180
      IF (NR.LE.0) GO TO 8                                              QS043190
      IF (.NOT.SIZE(R,II,NR)) CALL ORDER (R,II,NR)                      QS043200
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      DO 6 N=1,NR                                                       QS043210
      XVAL=R(N)+A(M)                                                    QS043220
      IF (XVAL.GT.XMIN) GO TO 7                                         QS043230
    6 CONTINUE                                                          QS043240
      GO TO 8                                                           QS043250
    7 IF (LAST .OR. XVAL.LE.XMAX) X=XVAL                                QS043260
      IF(ABS(XVAL-XMAX).LE.1.E-04)X=XVAL                                QS043270
    8 XNTRP=X.NE.XIN                                                    QS043280
                                                                        QS043290
C.....IF NO SOLUTION FOUND, KEEP SEARCHING.                             QS043300
    9 IF (XNTRP.OR.LAST) RETURN                                         QS043310
      DX=EPSLON*(ABS(XMAX)+ABS(XMIN))                                   QS043320
      GO TO 1                                                           QS043330
      END                                                               QS043340
      SUBROUTINE BNTRP (A,X,NA)                                         QS043350
C.....CALCULATION OF MATRIX B BY WHICH COEFFICIENTS OF THE POLYNOMIAL   QS043360
C     USED IN DOUBLE 3-POINT INTERPOLATION MAY BE OBTAINED.             QS043370
C                                                                       QS043380
C     IF     F(X) = C(1) + C(2)*(X-A(M)) + C(3)*(X-A(M))**2 +...        QS043390
C                                                                       QS043400
C     IS THE POLYNOMIAL USED IN THE NEIGHBORHOOD OF X, THE COEFFICIENTS QS043410
C     CAN BE OBTAINED FROM MATRIX B BY:                                 QS043420
C                                                                       QS043430
C            C(J) = B(1,J)*F(I) + B(2,J)*F(I+1) +...                    QS043440
C                                                                       QS043450
C     FOR A TOTAL OF L VALUES OF C AND F (AT MOST 4) WHERE L AND I ARE  QS043460
C     FOUND IN COMMON /NTRPC1/ AND M AND B ARE FOUND IN COMMON /NTRPC5/.QS043470
                                                                        QS043480
      REAL A(NA)                                                        QS043490
      COMMON /NTRPC1/ L,I,A11,A12,A13,A14,A22,A23,A24,A33,A34,A44       QS043500
      COMMON /NTRPC5/ M,B11,B21,B31,B41,B12,B22,B32,B42,B13,B23,B33,    QS043510
     1                B43,B14,B24,B34,B44                               QS043520
                                                                        QS043530
C.....SET UP COMMON BLOCK /NTRPC1/                                      QS043540
      CALL FNTRPA (A,X,NA)                                              QS043550
      IF (L.GT.1) GO TO 2                                               QS043560
                                                                        QS043570
C.....ENTER HERE FOR ONLY ONE COEFFICIENT.                              QS043580
    1 M=I                                                               QS043590
      B11=1.0                                                           QS043600
      RETURN                                                            QS043610
                                                                        QS043620
C.....ENTER HERE FOR 2 OR MORE COEFFICIENTS.                            QS043630
    2 M=I+1                                                             QS043640
      Q=1.0/A12                                                         QS043650
      IF (L.GT.2) GO TO 3                                               QS043660
      B12=Q                                                             QS043670
      B22=-Q                                                            QS043680
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      GO TO 24

C.....FNTER HERE FOR 3 OR MORE COEFFICIENTS.
3     P=1.0/A23
      IF (L.GT.3) GO TO 4
      B13=Q/A13
      B23=-Q*P
      B33=P/A13
      GO TO 34

C.....ENTER HERE FOR 4 COEFFICIENTS.
4     P2=P*P
      B14=P*Q/A13
      B24=-P2/A12-P2/A24
      B34=P2/A34+P2/A13
      B44=-P/A34/A24
      B13=(Q+Q)/A13
      B23=-P*(Q+Q)-P/A24
      B33=P2*(A24/A34+(A23-A12)/A13)
      B43=-1.0/A34/A24
      B41=0.0
      B42=0.0
34    B12=A23/A12/A13
      B22=P-Q
      B32=-A12/A13/A23
      B31=0.0
24    B11=0.0
      B21=1.0
      RETURN
      END
      INTEGER FUNCTION NRRTS3 (C,R)
C.....FINDS REAL ROOTS R, OF A CUBIC WITH COEFFICIENTS C, WHEN:
C                C(1) + C(2)*X + C(3)*X**2 + C(4)*X**3 = 0.0

      REAL C(4),R(3),K1,K2
      DATA THIRD,K1,K2/0.3333333,2.094395,4.188790/
      QRT(ARG)=SIGN(ABS(ARG)**THIRD,ARG)

C.....CONVERT TO NORMAL FORM AND CALCULATE NORMAL COEFFICIENTS.
      CNORM=3.0*C(4)
      P=C(3)/CNORM
      Q=C(2)/CNORM
      B=P**3-1.5*(P*Q-C(1)/CNORM)
      B2=B**2
      A=Q-P*P
      A3=A**3
      RAD=B2+A3
      IF (RAD) 3,2,1
```

```
                                                                        QS044170
C.....THERE IS ONE REAL ROOT.                                           QS044180
1     NRRTS3=1                                                          QS044190
      IF (RAD.NE.0.0) RAD=SQRT(RAD)                                     QS044200
      A=-B+RAD                                                          QS044210
      B=-B-RAD                                                          QS044220
      IF (A.NE.0.0) A=QRT(A)                                            QS044230
      IF (B.NE.0.0) B=QRT(B)                                            QS044240
      R(1)=A+B                                                          QS044250
      GO TO 10                                                          QS044260
                                                                        QS044270
C.....THERE ARE TWO REAL ROOTS.                                         QS044280
2     NRRTS3=2                                                          QS044290
      IF (B.EQ.0.0) GO TO 1                                             QS044300
      R(1)=QRT(B)                                                       QS044310
      R(2)=-2.0*R(1)                                                    QS044320
      GO TO 10                                                          QS044330
                                                                        QS044340
C.....THERE ARE THREE REAL ROOTS.                                       QS044350
3     NRRTS3=3                                                          QS044360
      PHI= ARCOS(SIGN(SQRT(-B2/A3),-B))/3.0                             QS044370
      CR=2.0*SQRT(-A)                                                   QS044380
      R(1)=CR*COS(PHI)                                                  QS044390
      R(2)=CR*COS(PHI+K1)                                               QS044400
      R(3)=CR*COS(PHI+K2)                                               QS044410
                                                                        QS044420
C.....CONVERT BACK TO ORIGINAL FORM.                                    QS044430
10    DO 11 I=1,NRRTS3                                                  QS044440
11    R(I)=R(I)-P                                                       QS044450
      RETURN                                                            QS044460
                                                                        QS044470
      ENTRY NRRTS2 (C,R)                                                QS044480
C.....FINDS REAL ROOTS R, OF A QUADRATIC WITH COEFFICIENTS C, WHEN:     QS044490
C             C(1) + C(2)*X + C(3)*X**2 + = 0.0                         QS044500
                                                                        QS044510
                                                                        QS044520
C.....CALCULATE RADICAL.                                                QS044530
      RAD=C(2)**2-4.0*C(3)*C(1)                                         QS044540
      IF (RAD) 21,22,23                                                 QS044550
                                                                        QS044560
C.....NO REAL ROOTS.                                                    QS044570
21    NRRTS3=0                                                          QS044580
      NRRTS2=0                                                          QS044590
      RETURN                                                            QS044600
C.....ONE REAL ROOT.                                                    QS044610
22    NRRTS3=1                                                          QS044620
      R(1)=-C(2)/2.0/C(3)                                               QS044630
      NRRTS2=1                                                          QS044640
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      RETURN                                                            QS044650
                                                                        QS044660
C.....TWO REAL ROOTS.                                                   QS044670
23    NRRTS3=2                                                          QS044680
      RAD=SQRT(RAD)                                                     QS044690
      TWOA=2.0*C(3)                                                     QS044700
      R(1)=-(RAD+C(2))/TWOA                                             QS044710
      R(2)=+(RAD-C(2))/TWOA                                             QS044720
      NRRTS2=2                                                          QS044730
      RETURN                                                            QS044740
      END                                                               QS044750
      LOGICAL FUNCTION SIZE (X,I,N)                                     QS044760
C.....CREATES THE POINTER ARRAY I, ORDERED BY SIZE OF X.                QS044770
C.....VALUE IS .TRUE. IF X ARRAY IS IN ORDER.                           QS044780
      DIMENSION X(3),I(3)                                               QS044790
      COMPLEX Z(3),ZS                                                   QS044800
      SIZE=.TRUE.                                                       QS044810
      DO 2 J=1,N                                                        QS044820
      K=J                                                               QS044830
1     IF (K.LE.1) GO TO 2                                               QS044840
      L=I(K-1)                                                          QS044850
      IF (X(J).GE.X(L)) GO TO 2                                         QS044860
      I(K)=L                                                            QS044870
      K=K-1                                                             QS044880
      SIZE=.FALSE.                                                      QS044890
      GO TO 1                                                           QS044900
2     I(K)=J                                                            QS044910
      RETURN                                                            QS044920
      ENTRY ORDER (X,I,N)                                               QS044930
      ORDER=0.                                                          QS044940
C.....REARRANGES X ARRAY ACCORDING TO POINTER ARRAY I.                  QS044950
      DO 14 J=1,N                                                       QS044960
      IF (I(J).LE.0) GO TO 13                                           QS044970
      M=J                                                               QS044980
      S=X(M)                                                            QS044990
11    L=I(M)                                                            QS045000
      I(M)=-L                                                           QS045010
      IF (L.EQ.J) GO TO 12                                              QS045020
      X(M)=X(L)                                                         QS045030
      M=L                                                               QS045040
      GO TO 11                                                          QS045050
12    X(M)=S                                                            QS045060
13    I(J)=IABS(I(J))                                                   QS045070
14    CONTINUE                                                          QS045080
      RETURN                                                            QS045090
      ENTRY ZORDER (Z,I,N)                                              QS045100
      ZORDER=0.                                                         QS045110
C.....REARRANGES Z (COMPLEX) ARRAY ACCORDING TO POINTER ARRAY I.        QS045120
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C     COMPLEX Z(N),ZS THIS WAS MOVED UP TO COMPILE PROPERLY ON NPS 370  QS045130
      DO 24 J=1,N                                                       QS045140
      IF (I(J).LE.0) GO TO 23                                           QS045150
      M=J                                                               QS045160
      ZS=Z(M)                                                           QS045170
21    L=I(M)                                                            QS045180
      I(M)=-L                                                           QS045190
      IF (L.EQ.J) GO TO 22                                              QS045200
      Z(M)=Z(L)                                                         QS045210
      M=L                                                               QS045220
      GO TO 21                                                          QS045230
22    Z(M)=ZS                                                           QS045240
23    I(J)=IABS(I(J))                                                   QS045250
24    CONTINUE                                                          QS045260
      RETURN                                                            QS045270
      END                                                               QS045280
      SUBROUTINE PJGRID(ZET,ET,ZCAM,IMAXY,PITCH)                        QS045290
                                                                        QS045300
                                                                        QS045310
C               ELECTROSTATIC ANALOG GRID GENERATOR                     QS045320
                                                                        QS045330
C                    J. J. ADAMCZYK                                     QS045340
C               NASA LEWIS RESEARCH CENTER 1980                         QS045350
                                                                        QS045360
                                                                        QS045370
C                  (SEE REF. 2, QSONIC USERS MANUAL)                    QS045380
                                                                        QS045390
                                                                        QS045400
      COMMON/ENTIRE/  X(100,30),Y(100,30),ETA(100,30) ,ZETA(100,30)     QS045410
      COMMON/CROSS/XQ(4,100),YQ(4,100),EQ(4,100),ZQ(4,100),ZETB(100),   QS045420
     1STREN(63),FUN(100),GUN1(100),ARG(100),ZBODY(63),DTREN(63)         QS045430
      COMMON/GEOM/NZGRID,NEGRID,RLE,RTE,C,CHORB,XUPS,XDNS,STAG,CC,CAP(4)QS045440
     1,PI                                                               QS045450
     1,RNK,VB,KN,NUM                                                    QS045460
      COMPLEX A,B,ZO,ZA,ZB,ZTEMP,ZTEMQ                                  QS045470
      COMPLEX SUM3,SUM4,SUM5,SUM6,STREN                                 QS045480
      COMPLEX SUMD,HSIN                                                 QS045490
      COMPLEX ZTEL,AI,HTAN,Z,SUM                                        QS045500
      COMPLEX SOUR,ZCAM,ZBODY,ZPET                                      QS045510
      COMPLEX ZST                                                       QS045520
      DOUBLE PRECISION DTREN,BINF                                       QS045530
      DIMENSION ZPET(100,30),ZCAM(100),ET(100),ZET(100)                 QS045540
      EQUIVALENCE (ZPET(1,1),ETA(1,1))                                  QS045550
      COMMON/CRHOSS/ BINF(63,63),SOUR(63,63)                            QS045560
      LOGICAL XNTRP,TEST                                                QS045570
      NETA0=50                                                          QS045580
      NZET0=50                                                          QS045590
      NZET4=50                                                          QS045600
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      IMID=1                                                            QS045610
      NUMX=31                                                           QS045620
      NUMY=14                                                           QS045630
      NUMZ=16                                                           QS045640
C                                                                       QS045650
C     NZGRID MUST BE ODD                                                QS045660
C                                                                       QS045670
      AI=CMPLX(0.0,1.0)                                                 QS045680
      PI=3.1415927                                                      QS045690
      CHORD=CHORB*COS(STAG)                                             QS045700
      STAG=STAG*180./PI                                                 QS045710
      S=PITCH                                                           QS045720
      WRITE(6,1006) NEGRID,NZGRID,IMAXY                                 QS045730
1006  FORMAT(5X,'NEGRID= ',I3,' NZGRID,ODD= ',I3,' IMAXY= ',I3)         QS045740
10    CONTINUE                                                          QS045750
      WRITE(6,1020)                                                     QS045760
1020  FORMAT(10X,'SURFACE COORDINATES')                                 QS045770
      WRITE(6,1030) (ZCAM(I),I=1,NUM)                                   QS045780
1030  FORMAT(7X,2F12.7)                                                 QS045790
      WRITE(6,1040) NUM,PITCH,CHORD,STAG                                QS045800
1040  FORMAT(4X,'NUMBER OF BODY POINTS',I5,10X,'PITCH',F12.7,10X,' CHO 'QS045810
     1,F12.7,' STAGGER',F12.7)                                          QS045820
      ZST=ZCAM(1)                                                       QS045830
      DO 25 I=1,NUM                                                     QS045840
      ZCAM(I)=ZCAM(I)-ZST                                               QS045850
25    CONTINUE                                                          QS045860
      MUM=NUM-1                                                         QS045870
      PSAVE=PITCH                                                       QS045880
      PITCH=2.0*PITCH                                                   QS045890
      XMAX=0.0                                                          QS045900
      IMAX=1                                                            QS045910
      DO 6000 I=1,NUM                                                   QS045920
      IF(XMAX .LE. REAL(ZCAM(I))) XMAX=REAL(ZCAM(I))                    QS045930
      IF(XMAX .LE. REAL(ZCAM(I))) IMAX=I                                QS045940
6000  CONTINUE                                                          QS045950
      DO 30 I=1,MUM                                                     QS045960
      IF(IMID .EQ. 1) ZBODY(I)=(ZCAM(I)+ZCAM(I+1))/2.0                  QS045970
      DO 30 J=1,MUM                                                     QS045980
      A=ZCAM(J)                                                         QS045990
      B=ZCAM(J+1)                                                       QS046000
      ZO=(A+B)/2.0                                                      QS046010
      ZA=CLOG(PI/PITCH*(ZBODY(I)-A))                                    QS046020
      ZB=CLOG(PI/PITCH*(ZBODY(I)-B))                                    QS046030
      IF(I .EQ. J) ZA=ZA                                                QS046040
      IF(I .EQ. J  .AND. AIMAG(ZB) .LT. 0.0 .AND. J .LT. IMAX) ZB=ZB+2.0QS046050
     **AI*PI                                                            QS046060
      IF(I .LT. J .AND. AIMAG(ZA) .LT. 0.0 .AND. I .LT. IMAXY) ZA=ZA+2.0QS046070
     **AI*PI                                                            QS046080
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      IF(I .LT. J .AND. AIMAG(ZB) .LT. 0.0 .AND. I .LT. IMAXY) ZB=ZB+2.0QS046090
     **AI*PI                                                            QS046100
      IF(I .GT. J) ZA=ZA                                                QS046110
      IF(I .GT. J) ZB=ZB                                                QS046120
      IF(I .GE. J .AND. J .GE. IMAX/2.0 .AND. AIMAG(ZA) .GT. PI/2.0) ZA=QS046130
     *ZA-2.0*PI*AI                                                      QS046140
      IF(I .GT. J .AND. J.GE. IMAX/2.0 .AND. AIMAG(ZB) .GT. PI/2.0)ZB=ZBQS046150
     *-2.0*PI*AI                                                        QS046160
 4000 CONTINUE                                                          QS046170
      SOUR(I,J)=(ZBODY(I)-A)*ZA-(ZBODY(I)-B)*ZB+(A-B)                   QS046180
      ZTEL=(ZBODY(I)-ZO)*PI/PITCH                                       QS046190
      HTAN=(CEXP(ZTEL)-CEXP(-ZTEL))/(CEXP(ZTEL)+CEXP(-ZTEL))            QS046200
      IF(CABS(ZTEL) .EQ. 0.0) SOUR(I,J)=SOUR(I,J)                       QS046210
      IF(CABS(ZTEL) .NE. 0.0) SOUR(I,J)=SOUR(I,J)+CLOG(HTAN/ZTEL)*(B-A) QS046220
      A1=ABS(REAL(B-A))                                                 QS046230
      A2=ABS(AIMAG(B-A))                                                QS046240
      IF(A1 .GE. A2) BINF(I,J)=REAL(SOUR(I,J))+AIMAG(B-A)/REAL(B-A)*AIMAQS046250
     *G(SOUR(I,J)))                                                     QS046260
      IF(A1 .LT. A2) BINF(I,J)=-AIMAG(SOUR(I,J))-REAL(B-A)/AIMAG(B-A)*REQS046270
     *AL(SOUR(I,J)))                                                    QS046280
   30 CONTINUE                                                          QS046290
C                                                                       QS046300
C     SOLUTION OF LINEAR EQUATIONS FOR ELECTROSTATIC CHARGE STRENGTH DISQS046310
C     TRIBUTION                                                         QS046320
C                                                                       QS046330
      IF(NUM .GT. 1) GO TO 40                                           QS046340
      STREN(1)=1.0/BINF(1,1)                                            QS046350
      GO TO 50                                                          QS046360
   40 CONTINUE                                                          QS046370
      DO 45 I=1,MUM                                                     QS046380
      DTREN(I)=1.0D0                                                    QS046390
   45 CONTINUE                                                          QS046400
                                                                        QS046410
                                                                        QS046420
      CALL CHLSKY(BINF,DTREN,MUM)                                       QS046430
   50 CONTINUE                                                          QS046440
                                                                        QS046450
                                                                        QS046460
                                                                        QS046470
      DO 51 I=1,MUM                                                     QS046480
      A=ZCAM(I)                                                         QS046490
      B=ZCAM(I+1)                                                       QS046500
      A1=ABS(REAL(B-A))                                                 QS046510
      A2=ABS(AIMAG(B-A))                                                QS046520
      STEMP=DTREN(I)                                                    QS046530
      IF(A1 .GE. A2)  STREN(I)=STEMP-AI*STEMP*AIMAG(B-A)/REAL(B-A)      QS046540
      IF(A1 .LT. A2) STREN(I)=-STEMP*REAL(B-A)/AIMAG(B-A)+AI*STEMP      QS046550
   51 CONTINUE                                                          QS046560
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      DO 55  I=1,MUM                                                    QS046570
      SUM2=0.0                                                          QS046580
      SUM7=0.0                                                          QS046590
      DO 56  J=1,MUM                                                    QS046600
      A=ZCAM(J)                                                         QS046610
      B=ZCAM(J+1)                                                       QS046620
      A1=ABS(REAL(B-A))                                                 QS046630
      A2=ABS(AIMAG(B-A))                                                QS046640
      IF(A1  .GE.  A2)  SUM2=SUM2+BINF(I,J)*REAL(STREN(J))              QS046650
      IF(A1  .LT.  A2)  SUM2=SUM2+BINF(I,J)*AIMAG(STREN(J))             QS046660
      FUN1=AIMAG(SOUR(I,J))-REAL(SOUR(I,J))*AIMAG(B-A)/REAL(B-A)        QS046670
      SUM7=SUM7+REAL(STREN(J))*FUN1                                     QS046680
56    CONTINUE                                                          QS046690
      ZETB(I)=SUM7                                                      QS046700
55    CONTINUE                                                          QS046710
      CHORX=CHORD                                                       QS046720
      DELX=3.0*CHORX/(NUMX-1.0)                                         QS046730
      DO 60  I=1,1                                                      QS046740
      DO 60  J=1,NUMY                                                   QS046750
      X(I,J)=-2.0*PSAVE                                                 QS046760
60    CONTINUE                                                          QS046770
      DELY=PSAVE/(NUMY-2)                                               QS046780
      DO 70  I=1,1                                                      QS046790
      DO 70  J=1,NUMY                                                   QS046800
      Y(I,J)=DELY*(J-2)                                                 QS046810
      IF(J  .EQ.  1)  Y(I,J)=-0.00001                                   QS046820
      IF(J  .EQ.  2)  Y(I,J)=0.00001                                    QS046830
      SUM=0.0                                                           QS046840
      Z=X(I,J)+AI*Y(I,J)                                                QS046850
      IF(X(I,J)  .LT.  0.0  .OR.  X(I,J)  .GT.  XMAX)  GO TO  7031      QS046860
      DO  7060  L=1,IMAX                                                QS046870
      IF(X(I,J)  .GE.  REAL(ZCAM(L))  .AND.  X(I,J)  .LE.  REAL(ZCAM(L+1))) GQS046880
     *O  TO  7080                                                       QS046890
7060  CONTINUE                                                          QS046900
7080  CONTINUE                                                          QS046910
      L1=L                                                              QS046920
      DO  7100  L=IMAX,NUM                                              QS046930
      IF(X(I,J)  .LE.  REAL(ZCAM(L))  .AND.  X(I,J)  .GE.  REAL(ZCAM(L+1))) GOQS046940
     *  TO  7120                                                        QS046950
7100  CONTINUE                                                          QS046960
7120  CONTINUE                                                          QS046970
      L2=L                                                              QS046980
      YA=AIMAG(ZCAM(L1))                                                QS046990
      YB=AIMAG(ZCAM(L1+1))                                              QS047000
      XA=REAL(ZCAM(L1))                                                 QS047010
      XB=REAL(ZCAM(L1+1))                                               QS047020
      Y1=YA+(YB-YA)/(XB-XA)*(X(I,J)-XA)                                 QS047030
      YA=AIMAG(ZCAM(L2))                                                QS047040
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      YB=AIMAG(ZCAM(L2+1))                                              QS047050
      XA=REAL(ZCAM(L2))                                                 QS047060
      XB=REAL(ZCAM(L2+1))                                               QS047070
      Y2=YA+(YB-YA)/(XB-XA)*(X(I,J)-XA)                                 QS047080
 7031 CONTINUE                                                          QS047090
      DO 75  IX=1,MUM                                                   QS047100
      A=ZCAM(IX)                                                        QS047110
      B=ZCAM(IX+1)                                                      QS047120
      ZA=CLOG(PI/PITCH*(Z-A))                                           QS047130
      ZB=CLOG(PI/PITCH*(Z-B))                                           QS047140
      IF(X(I,J) .GT. 0.0) GO TO 7000                                    QS047150
      IFLA=1                                                            QS047160
      IF(Y(I,J) .GE. 0.0) GO TO 7010                                    QS047170
      ZA=ZA                                                             QS047180
      ZB=ZB                                                             QS047190
      GO TO 7020                                                        QS047200
 7010 CONTINUE                                                          QS047210
      IF(AIMAG(ZA) .LT. 0.0) ZA=ZA+2.0*AI*PI                            QS047220
      IF(AIMAG(ZB) .LT. 0.0) ZB=ZB+2.0*AI*PI                            QS047230
      GO TO 7020                                                        QS047240
 7000 CONTINUE                                                          QS047250
      IF(X(I,J) .GT. XMAX) GO TO 7040                                   QS047260
      IF(Y(I,J) .LT. Y1 .AND. Y(I,J) .GT. Y2) IFLA=2                    QS047270
      IF(Y(I,J) .LT. Y1) GO TO 7140                                     QS047280
      IF(AIMAG(ZA) .LT. -PI/2.0) ZA=ZA+2.0*AI*PI                        QS047290
      IF(AIMAG(ZB) .LT. -PI/2.0) ZB=ZB+2.0*AI*PI                        QS047300
      GO TO 7020                                                        QS047310
 7140 CONTINUE                                                          QS047320
      IF(Y(I,J) .LE. Y2) GO TO 7160                                     QS047330
      IF(AIMAG(ZA) .LT. 0.0 .AND. IX .GE. IMAX) ZA=ZA+2.0*AI*PI         QS047340
      IF(AIMAG(ZB) .LT. 0.0 .AND. IX .GE. IMAX) ZB=ZB+2.0*AI*PI         QS047350
      GO TO 7020                                                        QS047360
 7160 CONTINUE                                                          QS047370
      ZA=ZA                                                             QS047380
      ZB=ZB                                                             QS047390
      IF(IX .GE. IMAXY .AND. AIMAG(ZA) .GT. PI/2.0) ZA=ZA-2.0*PI*AI     QS047400
      IF(IX .GE. IMAXY .AND. AIMAG(ZB) .GT. PI/2.0) ZB=ZB-2.0*PI*AI     QS047410
      GO TO 7020                                                        QS047420
 7040 CONTINUE                                                          QS047430
      IFLA=1                                                            QS047440
      ZA=ZA                                                             QS047450
      ZB=ZB                                                             QS047460
 7020 CONTINUE                                                          QS047470
 5000 CONTINUE                                                          QS047480
      SUM=SUM+STREN(IX)*(A-B+(Z-A)*ZA-(Z-B)*ZB)                         QS047490
      ZO=(A+B)/2.0                                                      QS047500
      ZTEL=(Z-ZO)*PI/PITCH                                              QS047510
      HTAN=(CEXP(ZTEL)-CEXP(-ZTEL))/(CEXP(ZTEL)+CEXP(-ZTEL))            QS047520
```

```
      SUM=SUM+STREN(IX)*CLOG(HTAN/ZTEL)*(B-A)                           QS047530
      IF(I .GT. 1 .AND. I .LT. NUMX) GO TO 3010                         QS047540
      SUM3=(A-B)+(Z-A)*ZA-(Z-B)*ZB                                      QS047550
      SUM3= SUM3*STREN(IX)                                              QS047560
      SUM4=CLOG(HTAN/ZTEL)*(B-A)                                        QS047570
      SUM4= SUM4*STREN(IX)                                              QS047580
      SUM5=CLOG(1.0/ZTEL)*(B-A)                                         QS047590
      SUM5= SUM5*STREN(IX)                                              QS047600
      SUM6=CLOG(HTAN)*(B-A)                                             QS047610
      SUM6= SUM6*STREN(IX)                                              QS047620
3010  CONTINUE                                                          QS047630
75    CONTINUE                                                          QS047640
      ETA(I,J)=REAL(SUM)                                                QS047650
      IF(X(I,J) .LT.  XMAX .AND. X(I,J) .GT. 0.0 .AND. Y(I,J) .LT. Y1 . QS047660
     *AND                                                               QS047670
     1.Y(I,J) .GT. Y2) ETA(I,J)=1.05                                    QS047680
      ZETA(I,J)=AIMAG(SUM)                                              QS047690
70    CONTINUE                                                          QS047700
      NUMD=NUMY-1                                                       QS047710
      DO 310 ID=1,NUMD                                                  QS047720
      ARG(ID)=Y(1,ID+1)                                                 QS047730
      FUN(ID)=ETA(1,ID+1)                                               QS047740
      GUN1(ID)=ZETA(1,ID+1)                                             QS047750
310   CONTINUE                                                          QS047760
      FO=0.0                                                            QS047770
      YSTAR2=.95*PSAVE/2.                                               QS047780
      TEST=XNTRP(ARG,FUN,FO,NUMD,YSTAR2)                                QS047790
      ZETA2=FNTRP(ARG,GUN1,YSTAR2,NUMD)                                 QS047800
      ETEST=0.0                                                         QS047810
      ITEST=1                                                           QS047820
      DO 330 I=1,NUMD                                                   QS047830
      IF(ETEST .LE. ETA(1,I+1)) ETEST=ETA(1,I+1)                        QS047840
      IF(ETEST .LE. ETA(1,I+1)) ITEST=I                                 QS047850
330   CONTINUE                                                          QS047860
      IF(ITEST .EQ. 1) ITEST=2                                          QS047870
      AQ1=ZETA(1,ITEST+1)                                               QS047880
      DELT=Y(1,4)-Y(1,2)                                                QS047890
      AQ2=(ZETA(1,ITEST+2)-ZETA(1,ITEST))/(2.0*DELT)                    QS047900
      AQ3=(ZETA(1,ITEST+2)+ZETA(1,ITEST)-2.0*ZETA(1,ITEST+1))/(2.0*DELT*QS047910
     **2)                                                               QS047920
      BQ2=(ETA(1,ITEST+2)-ETA(1,ITEST))/(2.0*DELT)                      QS047930
      BQ3=(ETA(1,ITEST+2)+ETA(1,ITEST)-2.0*ETA(1,ITEST+1))/(2.0*DELT**2)QS047940
      YLMAX=-BQ2/(2.0*BQ3)                                              QS047950
      ZETA4=AQ1+AQ2*YLMAX+AQ3*YLMAX**2                                  QS047960
      DELZ=ZETA(1,2)-ZETA(1,1)                                          QS047970
      DO 360 I=1,MUM                                                    QS047980
      ARG(I)=ZETB(I)                                                    QS047990
      FUN(I)=REAL(ZBODY(I))                                             QS048000
```

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360   CONTINUE                                                          QS048010
      XBOD1=FNTRP(ARG,FUN,ZETA4,MUM)                                    QS048020
      XBOD3=FNTRP(ARG,FUN,0.0,MUM)                                      QS048030
      DO 370 I=1,MUM                                                    QS048040
      FUN(I)=AIMAG(ZBODY(I))                                            QS048050
370   CONTINUE                                                          QS048060
      YBOD1=FNTRP(ARG,FUN,ZETA4,MUM)                                    QS048070
      YBOD3=FNTRP(ARG,FUN,0.0,MUM)                                      QS048080
      ILIM=MUM+2                                                        QS048090
      XQ(1,1)=XBOD1                                                     QS048100
      XQ(1,ILIM)=XBOD1                                                  QS048110
      YQ(1,1)=YBOD1                                                     QS048120
      YQ(1,ILIM)=YBOD1                                                  QS048130
      ZQ(1,1)=ZETA4                                                     QS048140
      ZQ(1,ILIM)=-ZETA4                                                 QS048150
      EQ(1,1)=1.0                                                       QS048160
      EQ(1,ILIM)=1.0                                                    QS048170
      DO 380 I=1,MUM                                                    QS048180
      IF(ZETB(I) .GT. ZETA4)  GO TO 390                                 QS048190
380   CONTINUE                                                          QS048200
390   CONTINUE                                                          QS048210
      ISTART=I                                                          QS048220
      DO 410 I=ISTART,MUM                                               QS048230
      IL=I-ISTART+2                                                     QS048240
      XQ(1,IL)=REAL(ZBODY(I))                                           QS048250
      YQ(1,IL)=AIMAG(ZBODY(I))                                          QS048260
      ZQ(1,IL)=ZETB(I)                                                  QS048270
      EQ(1,IL)=1.0                                                      QS048280
410   CONTINUE                                                          QS048290
      IEND=ISTART-1                                                     QS048300
      DO 420 I=1,IEND                                                   QS048310
      IL=MUM-ISTART+2+I                                                 QS048320
      XQ(1,IL)=REAL(ZBODY(I))                                           QS048330
      YQ(1,IL)=AIMAG(ZBODY(I))                                          QS048340
      ZQ(1,IL)=ZETB(I)-DELZ                                             QS048350
      EQ(1,IL)=1.0                                                      QS048360
420   CONTINUE                                                          QS048370
                                                                        QS048380
C      DETERMINE LOCATION OF PERIODIC BOUNDARY POINTS                   QS048390
                                                                        QS048400
      DO 110 IL=2,4                                                     QS048410
      IF(IL .EQ. 2) YQ(2,1)=YSTAR2                                      QS048420
      IF(IL .EQ. 2) XQ(2,1)=-1.50*PSAVE                                 QS048430
      IF(IL .EQ. 2) EQ(2,1)=0.0                                         QS048440
      IF(IL .EQ. 2) ZQ(2,1)=ZETA2                                       QS048450
      IF(IL .EQ. 2) DELX=(CHORX+3.*PSAVE)/(NETA0-1.0)                   QS048460
      IF(IL .EQ. 2) IEND=NETA0                                          QS048470
                                                                        QS048480
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      IF(IL .EQ. 2) ETAO=0.0                                            QS048490
      IF(IL .EQ. 3) YQ(3,1)=YBOD3                                       QS048500
      IF(IL .EQ. 3) XQ(3,1)=XBOD3                                       QS048510
      IF(IL .EQ. 3) EQ(3,1)=1.0                                         QS048520
      IF(IL .EQ. 3) ZQ(3,1)=0.0                                         QS048530
      IF(IL .EQ. 3) DELX=(2.0*PSAVE)/(NZETO-1.0)                        QS048540
      IF(IL .EQ. 3) IEND=NZETO                                          QS048550
      IF(IL .EQ. 3) ZETAO=0.0                                           QS048560
      IF(IL .EQ. 4) YQ(4,1)=YBOD1                                       QS048570
      IF(IL .EQ. 4) XQ(4,1)=XBOD1                                       QS048580
      IF(IL .EQ. 4) EQ(4,1)=1.0                                         QS048590
      IF(IL .EQ. 4) ZQ(4,1)=ZETA4                                       QS048600
      IF(IL .EQ. 4) DELX=(-2.0*PSAVE-XBOD1)/(NZET4-1.0)                 QS048610
      IF(IL .EQ. 4) IEND=NZET4                                          QS048620
      IF(IL .EQ. 4) ZETAO=ZETA4                                         QS048630
      DO 110 I=2,IEND                                                   QS048640
      XQ(IL,I)=XQ(IL,I-1)+DELX                                          QS048650
      YQ(IL,I)=YQ(IL,I-1)                                               QS048660
      DO 120 ITOL=1,200                                                 QS048670
      SUM=0.0                                                           QS048680
      SUMD=0.0                                                          QS048690
      Z=XQ(IL,I)+AI*YQ(IL,I)                                            QS048700
      IF(XQ(IL,I) .LT. 0.0 .OR. XQ(IL,I) .GT. XMAX) GO TO 130           QS048710
      DO 140 L=1,IMAX                                                   QS048720
      IF(XQ(IL,I) .GE. REAL(ZCAM(L)) .AND. XQ(IL,I) .LE. REAL(ZCAM(L+1))QS048730
     *) GO TO 150                                                       QS048740
  140 CONTINUE                                                          QS048750
  150 CONTINUE                                                          QS048760
      L1=L                                                              QS048770
      DO 160 L=IMAX,NUM                                                 QS048780
      IF(XQ(IL,I) .LE. REAL(ZCAM(L)) .AND. XQ(IL,I) .GE. REAL(ZCAM(L+1))QS048790
     *) GO TO 170                                                       QS048800
  160 CONTINUE                                                          QS048810
  170 CONTINUE                                                          QS048820
      L2=L                                                              QS048830
      YA=AIMAG(ZCAM(L1))                                                QS048840
      YB=AIMAG(ZCAM(L1+1))                                              QS048850
      XA=REAL(ZCAM(L1))                                                 QS048860
      XB=REAL(ZCAM(L1+1))                                               QS048870
      Y1=YA+(YB-YA)/(XB-XA)*(XQ(IL,I)-XA)                               QS048880
      YA=AIMAG(ZCAM(L2))                                                QS048890
      YB=(AIMAG(ZCAM(L2+1)))                                            QS048900
      XA=REAL(ZCAM(L2))                                                 QS048910
      XB=REAL(ZCAM(L2+1))                                               QS048920
      Y2=YA+(YB-YA)/(XB-XA)*(XQ(IL,I)-XA)                               QS048930
  130 CONTINUE                                                          QS048940
      DO 180 IX=1,MUM                                                   QS048950
      A=ZCAM(IX)                                                        QS048960
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      B=ZCAM(IX+1)                                                      QS048970
      ZA=CLOG(PI/PITCH*(Z-A))                                           QS048980
      ZB=CLOG(PI/PITCH*(Z-B))                                           QS048990
      IF(XQ(IL,I) .GT. 0.0) GO TO 190                                   QS049000
      IF(YQ(IL,I) .GE.  0.0) GO TO 200                                  QS049010
      ZA=ZA                                                             QS049020
      ZB=ZB                                                             QS049030
      GO TO 210                                                         QS049040
  200 CONTINUE                                                          QS049050
      IF(AIMAG(ZA) .LT. 0.0) ZA=ZA+2.0*AI*PI                            QS049060
      IF(AIMAG(ZB) .LT. 0.0) ZB=ZB+2.0*AI*PI                            QS049070
      GO TO 210                                                         QS049080
  190 CONTINUF                                                          QS049090
      IF(XQ(IL,I) .GT. XMAX) GO TO 220                                  QS049100
      IF(YQ(IL,I) .LT. Y1) GO TO 230                                    QS049110
      IF(AIMAG(ZA) .LT. -PI/2.0) ZA=ZA+2.0*AI*PI                        QS049120
      IF(AIMAG(ZB) .LT. -PI/2.0) ZB=ZB+2.0*AI*PI                        QS049130
      GO TO 210                                                         QS049140
  230 CONTINUE                                                          QS049150
      IF(YQ(IL,I) .LE. Y2) GO TO 240                                    QS049160
      IF(AIMAG(ZA) .LT. 0.0 .AND. IX .GE. IMAX) ZA=ZA+2.0*AI*PI         QS049170
      IF(AIMAG(ZB) .LT. 0.0 .AND. IX .GE. IMAX) ZB=ZB+2.0*AI*PI         QS049180
      GO TO 210                                                         QS049190
  240 CONTINUE                                                          QS049200
      ZA=ZA                                                             QS049210
      ZB=ZB                                                             QS049220
      IF(IX .GE. IMAXY .AND . AIMAG(ZA) .GT. PI/2.0) ZA=ZA-2.0*PI*AI    QS049230
      IF(IX .GE. IMAXY .AND. AIMAG(ZB) .GT. PI/2.0) ZB=ZB-2.0*PI*AI     QS049240
      GO TO 210                                                         QS049250
  220 CONTINUE                                                          QS049260
      ZA=ZA                                                             QS049270
      ZB=ZB                                                             QS049280
  210 CONTINUE                                                          QS049290
      SUM=SUM+STREN(IX)*(A-B+(Z-A)*ZA-(Z-B)*ZB)                         QS049300
      SUMD=SUMD+STREN(IX)*(ZA-ZB)                                       QS049310
      ZO=(A+B)/2.0                                                      QS049320
      ZTEL=(Z-ZO)*PI/PITCH                                              QS049330
      HTAN=(CEXP(ZTEL)-CEXP(-ZTEL))/(CEXP(ZTEL)+CEXP(-ZTEL))            QS049340
      HSIN=0.5*(CEXP(ZTEL*2.0)-CEXP(-ZTEL*2.0))                         QS049350
      SUM=SUM+STREN(IX)*CLOG(HTAN/ZTEL)*(B-A)                           QS049360
      SUMD=SUMD+STREN(IX)*(PI/PSAVE/HSIN-1.0/(Z-ZO))*(B-A)              QS049370
  180 CONTINUE                                                          QS049380
      ETAF=REAL(SUM)                                                    QS049390
      ZETAF=AIMAG(SUM)                                                  QS049400
      ETAFD=AIMAG(SUMD)                                                 QS049410
      ZETAFD=-REAL(SUMD)                                                QS049420
      F1=ETAO-ETAF                                                      QS049430
      G1=ZETAO-ZETAF                                                    QS049440
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      DELY1=-F1/ETAFD                                                   QS049450
      DELY2=-G1/ZETAFD                                                  QS049460
      IF(IL .EQ. 2) DELT=DELY1                                          QS049470
      IF(IL .GT. 2) DELT=DELY2                                          QS049480
      YQ(IL,I)=YQ(IL,I)+DELT                                            QS049490
      IF(ABS(DELT) .LT. 1.E-06) GO TO 250                               QS049500
  120 CONTINUE                                                          QS049510
  250 CONTINUE                                                          QS049520
      IF(IL .EQ. 2) EQ(IL,I)=0.0                                        QS049530
      IF(IL .EQ. 2) ZQ(IL,I)=ZETAF                                      QS049540
      IF(IL .EQ. 3) EQ(IL,I)=ETAF                                       QS049550
      IF(IL .EQ.3) ZQ(IL,I)=0.0                                         QS049560
      IF(IL .EQ. 4) EQ(IL,I)=ETAF                                       QS049570
      IF(IL .EQ. 4) ZQ(IL,I)=ZETA4                                      QS049580
  110 CONTINUE                                                          QS049590
                                                                        QS049600
                                                                        QS049610
                                                                        QS049620
                                                                        QS049630
      NEND=2*NZGRID-1                                                   QS049640
      DO 500 I=1,NEND                                                   QS049650
      DO 500 J=1,NEGRID                                                 QS049660
      ETA(I,J)=0.0                                                      QS049670
      ZETA(I,J)=0.0                                                     QS049680
      X(I,J)=0.0                                                        QS049690
      Y(I,J)=0.0                                                        QS049700
  500 CONTINUE                                                          QS049710
      DELZ=ZQ(4,1)/(NZGRID-1.0)                                         QS049720
      DELE=1.0/(NEGRID-1.0)                                             QS049730
      DO 510 I=1,NETAO                                                  QS049740
      ARG(I)=ZQ(2,I)                                                    QS049750
      FUN(I)=XQ(2,I)                                                    QS049760
      GUN1(I)=YQ(2,I)                                                   QS049770
  510 CONTINUE                                                          QS049780
      DO 520 J=1,NZGRID                                                 QS049790
      ETA(J,1)=0.0                                                      QS049800
      ZETA(J,1)=ZQ(4,1)-DELZ*(J-1.0)                                    QS049810
      RQ=ZETA(J,1)                                                      QS049820
      X(J,1)=FNTRP(ARG,FUN,RQ,NETAO)                                    QS049830
      Y(J,1)=FNTRP(ARG,GUN1,RQ,NETAO)                                   QS049840
  520 CONTINUE                                                          QS049850
      NEND=2*NZGRID-1                                                   QS049860
      ISTART=NZGRID+1                                                   QS049870
      DO 530 J=ISTART,NEND                                              QS049880
      IML=2*NZGRID-J                                                    QS049890
      ETA(J,1)=0.0                                                      QS049900
      ZETA(J,1)=-ZETA(IML,1)                                            QS049910
      X(J,1)=X(IML,1)                                                   QS049920
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      Y(J,1)=Y(IML,1)-PSAVE                                           QS049930
  530 CONTINUE                                                        QS049940
      ILIM=MUM+2                                                      QS049950
      DO 540 I=1,ILIM                                                 QS049960
      ARG(I)=ZQ(1,I)                                                  QS049970
      FUN(I)=XQ(1,I)                                                  QS049980
      GUN1(I)=YQ(1,I)                                                 QS049990
  540 CONTINUE                                                        QS050000
      DO 550 J=1,NEND                                                 QS050010
      ETA(J,NEGRID)=1.0                                               QS050020
      ZETA(J,NEGRID)=ZETA(J,1)                                        QS050030
      RQ=ZETA(J,NEGRID)                                               QS050040
      X(J,NEGRID)=FNTRP(ARG,FUN,RQ,ILIM)                              QS050050
      Y(J,NEGRID)=FNTRP(ARG,GUN1,RQ,ILIM)                             QS050060
  550 CONTINUE                                                        QS050070
      DO 560 I=1,NZET4                                                QS050080
      IML=NZET4+1-I                                                   QS050090
      ARG(I)=EQ(4,IML)                                                QS050100
      FUN(I)=XQ(4,IML)                                                QS050110
      GUN1(I)=YQ(4,IML)                                               QS050120
  560 CONTINUE                                                        QS050130
      DO 570 I=1,NEGRID                                               QS050140
      ETA(1,I)=(I-1.0)*DELE                                           QS050150
      ZETA(1,I)=ZQ(4,1)                                               QS050160
      RQ=ETA(1,I)                                                     QS050170
      X(1,I)=FNTRP(ARG,FUN,RQ,NZET4)                                  QS050180
      Y(1,I)=FNTRP(ARG,GUN1,RQ,NZET4)                                 QS050190
  570 CONTINUE                                                        QS050200
      DO 580 I=1,NEGRID                                               QS050210
      ETA(NEND,I)=ETA(1,I)                                            QS050220
      ZETA(NEND,I)=-ZETA(1,I)                                         QS050230
      X(NEND,I)=X(1,I)                                                QS050240
      Y(NEND,I)=Y(1,I)                                                QS050250
  580 CONTINUE                                                        QS050260
      DO 585 I=1,NZETO                                                QS050270
      IML=NZETO+1-I                                                   QS050280
      ARG(I)=EQ(3,IML)                                                QS050290
      FUN(I)=XQ(3,IML)                                                QS050300
      GUN1(I)=YQ(3,IML)                                               QS050310
  585 CONTINUE                                                        QS050320
      DO 587 I=1,NEGRID                                               QS050330
      ETA(NZGRID,I)=(I-1.0)*DELE                                      QS050340
      ZETA(NZGRID,I)=0.0                                              QS050350
      RQ=ETA(NZGRID,I)                                                QS050360
      X(NZGRID,I)=FNTRP(ARG,FUN,RQ,NZETO)                             QS050370
      Y(NZGRID,I)=FNTRP(ARG,GUN1,RQ,NZETO)                            QS050380
  587 CONTINUE                                                        QS050390
      X(1,1)=-4.0*PSAVE                                               QS050400
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      X(NZGRID,1)=4.0*PSAVE                                             QS050410
      X(NEND,1)=-4.0*PSAVE                                              QS050420
      Y(1,1)=YQ(4,NZET4)                                                QS050430
      Y(NZGRID,1)=YQ(3,NZETO)                                           QS050440
      Y(NEND,1)=YQ(4,NZET4)                                             QS050450
                                                                        QS050460
      L=NEGRID                                                          QS050470
      L=NEND                                                            QS050480
      L=NZGRID                                                          QS050490
                                                                        QS050500
C      GIVEN PERIODIC BOUNDARY AND BLADE SHAPE, SOLVE THE BOUNDARY VALUEQS050510
C      PROBLEM                                                          QS050520
C      FOR THE INTERNAL GRID POINTS.                                    QS050530
                                                                        QS050540
      BIJ=2.0*(1.0/(DELE**2)+1.0/(DELZ**2))                             QS050550
      BIJP=1.0/(DELE**2)                                                QS050560
      BIJM=BIJP                                                         QS050570
      BIPJ=1.0/(DELZ**2)                                                QS050580
      BIMJ=BIPJ                                                         QS050590
      NEG2=NEGRID-1                                                     QS050600
      NZG2=NEND-1                                                       QS050610
      EPP=1.E-05                                                        QS050620
      DO 600 ITER=1,100                                                 QS050630
      ERR=0.0                                                           QS050640
      DO 610 I=2,NZG2                                                   QS050650
      DO 610 J=2,NEG2                                                   QS050660
      IF(I .EQ. NZGRID) GO TO 610                                       QS050670
      XHOLD=X(I,J)                                                      QS050680
      YHOLD=Y(I,J)                                                      QS050690
      X(I,J)=C/BIJ*(BIPJ*X(I+1,J)+BIMJ*X(I-1,J)+BIJP*X(I,J+1)+BIJM*X(I  QS050700
     *,J-1)) +(1.-C)*X(I,J)                                             QS050710
      Y(I,J)=C/BIJ*(BIPJ*Y(I+1,J)+BIMJ*Y(I-1,J)+BIJP*Y(I,J+1)+BIJM*Y(I  QS050720
     *,J-1)) +(1.-C)*Y(I,J)                                             QS050730
      ERR=ERR+ABS(X(I,J)-XHOLD)+ABS(Y(I,J)-YHOLD)                       QS050740
610   CONTINUE                                                          QS050750
      IF(ITER .LT. 5) GO TO 600                                         QS050760
      ERR=ERR/(2.0*NEG2*NZG2)                                           QS050770
      IF(ERR .LE. EPP) GO TO 670                                        QS050780
      KPRT=ITER/200                                                     QS050790
      IF(ITER .NE. 200*KPRT) GO TO 600                                  QS050800
      DO 620 I=1,NEND                                                   QS050810
620   CONTINUE                                                          QS050820
600   CONTINUE                                                          QS050830
                                                                        QS050840
                                                                        QS050850
                                                                        QS050860
                                                                        QS050870
670   CONTINUE                                                          QS050880
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      WRITE(6,4444) ITER,ERR                                            QS050890
4444  FORMAT(' ITER COUNT FOR INTERNAL GRID POINTS= ',I3,' ERR= ',E15.5)QS050900
      DO 650 I=1,NEND                                                   QS050910
      DO 650 J=1,NEGRID                                                 QS050920
      ZPET(I,J)=X(I,J)+AI*Y(I,J)                                        QS050930
650   CONTINUE                                                          QS050940
                                                                        QS050950
                                                                        QS050960
      MM=NEGRID                                                         QS050970
      NN=NEND                                                           QS050980
      K=1                                                               QS050990
      ZPET(1,1)=-2.0*CHORB+AI*YQ(4,NZET4)                               QS051000
      ZPET(NZGRID,1)=2.0*CHORB+AI*YQ(3,NZETO)                           QS051010
      ZPET(NEND,1)=-2.0*CHORB+AI*YQ(4,NZET4)                            QS051020
C     ZPET(1,1)=-2.*CHORX+0.                                            QS051030
C     ZPET(NEND,1)=ZPET(1,1)                                            QS051040
C     ZPET(NZGRID,1)=2.*CHORX+0.                                        QS051050
                                                                        QS051060
                                                                        QS051070
      DO 675 I=1,NEND                                                   QS051080
      DO 675 J=1,NEGRID                                                 QS051090
      ZPET(I,J)=ZPET(I,J)*CEXP(-AI*STAG*PI/180.0)                       QS051100
      X(I,J)=REAL(ZPET(I,J))                                            QS051110
      Y(I,J)=AIMAG(ZPET(I,J))                                           QS051120
675   CONTINUE                                                          QS051130
      ETADF1=-DELZ                                                      QS051140
      ETADF2=-ETADF1                                                    QS051150
      ZETDF1= DELE                                                      QS051160
      ZETDF2=-ZETDF1                                                    QS051170
      ET(1)=FLOAT(NZGRID-1)*(-DELZ)                                     QS051180
      ZET(1)=0.                                                         QS051190
      DO 4844 I1=2,NEND                                                 QS051200
4844  ET(I1)=DELZ+ET(I1-1)                                              QS051210
      DO 4845 I1=2,NEGRID                                               QS051220
4845  ZET(I1)=DELE+ZET(I1-1)                                            QS051230
      NOZ=NEND                                                          QS051240
      DO 780 I=1,NEND                                                   QS051250
      DO 780 J=1,NEGRID                                                 QS051260
      ZPET(I,J)=ZPET(I,J)*CEXP(AI*STAG*PI/180.0)                        QS051270
780   CONTINUE                                                          QS051280
      DO 790 I=1,NEND                                                   QS051290
      ZTEMP=(ZPET(I,NEGRID)+ZPET(I+1,NEGRID))/2.0                       QS051300
      ZTEMQ=ZTEMP*CEXP(-AI*STAG*PI/180.0)                               QS051310
      XT=REAL(ZTEMP)                                                    QS051320
      YT=AIMAG(ZTEMP)                                                   QS051330
      XR=REAL(ZTEMQ)                                                    QS051340
      YR=AIMAG(ZTEMQ)                                                   QS051350
790   CONTINUE                                                          QS051360
```

```
      STAG=STAG*PI/180.
      PITCH=PSAVE
      RETURN
      END
      SUBROUTINE CHLSKY(A,C,N)
      IMPLICIT REAL*8 (A-H,O-Z)
C - CHOLESKY - SOLVES AN N BY N SYSTEM OF EQUATIONS WITH COEFFICIENT
C   -
C   MATRIX A(I,J), CONSTANT VECTOR C(I), AND SOLUTION VECTOR.
C   CHOLESKYS METHOD IS USED.  IT REQUIRES N**2 + O(N) OPERATIONS.
C
      DIMENSION A(63,63),C(63)
C
C - CALCULATION OF SOLUTION MATRIX.  NOTE BOTH THE UPPER AND LOWER
C   TRIANGULAR MATRICES ARE STORED AS REPLACEMENT VALUES IN MATRIX A.
C   ALSO THE SOLUTION VECTOR REPLACES THE CONSTANT VECTOR (C).
C

      IST = 1
      JST = 2
      DO 50 K = 1,N
C
C - CALCULATION OF LOWER TRIANGULAR MATRIX ELEMENTS
C
      DO 10 I = IST,N
      J = 0
20    J = J+1
      IF (J.GE.K) GO TO 10
      A(I,K) = A(I,K) - A(I,J)*A(J,K)
      GO TO 20
10    CONTINUE
C
C - CALCULATION OF UPPER TRIANGULAR MATRIX ELEMENTS
C
      IF (K.EQ.N) GO TO 50
      DO 40 J = JST,N
      I = 0
30    I = I+1
      IF (I.GE.K) GO TO 40
      A(K,J) = A(K,J)-A(K,I)*A(I,J)
      GO TJ 30
40    A(K,J) = A(K,J)/A(K,K)
      IST = IST+1
50    JST = JST+1
C
C - CALCULATION OF CONSTANT VECTOR ELEMENTS.  ENTRY POINT FOR MULTIPLE
C   SOLUTION INVOLVING THE SAME COEFFICIENT MATRIX, BUT CHANGES IN
C   CONSTANT MATRIX.
```

```
C                                                                       QS051850
      ENTRY CHGCNT(A,C,N)                                               QS051860
      NP1 = N+1                                                         QS051870
      DO 70 K = 1,N                                                     QS051880
      I = 0                                                             QS051890
60    I = I+1                                                           QS051900
      IF (I.GE.K) GO TO 70                                              QS051910
      C(K) = C(K) - A(K,I)*C(I)                                         QS051920
      GO TO 60                                                          QS051930
70    C(K) = C(K)/A(K,K)                                                QS051940
C                                                                       QS051950
C - EVALUATION OF SOLUTION MATRIX                                        QS051960
C                                                                       QS051970
      DO 90 K = 1,N                                                     QS051980
      L = NP1-K                                                         QS051990
      M = NP1                                                           QS052000
80    M = M-1                                                           QS052010
      IF (M.LE.L) GO TO 90                                              QS052020
      C(L) = C(L)-A(L,M)*C(M)                                           QS052030
      GO TO 80                                                          QS052040
90    CONTINUE                                                          QS052050
      RETURN                                                            QS052060
      END                                                               QS052070
```

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